Fuel Research Institute News

Vol 20-21 (1970-71)

F.R.I News

Vol. 20, 21

1970-71

Vol. 20
No. 1

CFRI

MARCH
1970

CFTRI
He.
LIBRARY
21170
MYSORE

IN THIS ISSUE

EDITORIAL
(Problem of Coking Coal) - - - 1

DEMAND, RESERVES AND PLANNED PRODUCTION OF COKING COAL IN INDIA - - - - - - - - - - - - 2
A. Lahiri

SELECTION OF COKING BLEND FOR THE ROURKELA STEEL PLANT - - - - - - - 19
M. V. P. Menon, K. Singh, K. Raja, S. Biswas, N. G. Banerjee & A. K. Moitra

PROBLEM OF COKING COAL — A SYMPOSIUM - - 27
R. S. Saha, Samir Sen & S. R. R. Rao

SPOTLIGHT ON SCIENTIFIC ACTIVITIES

AROMATIC POLYCARBOXYLIC ACIDS BY NITRIC ACID OXIDATION OF COAL - - - - - - 33

CFRI SETS UP SMOKE DENSITY INDICATOR - - - - - - - - - 34

VARIATION OF COAL PROPERTIES IN RELATION TO DEPTH OF THE RANIGUNJ MEASURE COALS, RANIGAJ COALFIELD - 34

FUEL EFFICIENCY STUDIES ON INDUSTRIAL BOILERS - - - - 36

PYROGENIC WATER IN COAL - 37

NOTES & NEWS

CFRI SCIENTIFIC COMMITTEE MEETING - - - - - - - - - - 39

THE THIRTY-SEVENTH ANNUAL GENERAL MEETING OF ICOA - 40

THE SIXTH ANNUAL GENERAL MEETING OF SCPCA - - - - - 40

COMMERCIALIZATION OF CFRI PROCESSES - - - - - - - - - 40

CFRI PROCESS PATENTED ABROAD - - - - - - - - - - - - 40

CFRI PARTICIPATION IN SYMPOSIA - - - - - - - - - - - - 41

TRAINING AT CFRI - - - - - - 42

FOUNDATION FOR STONE LAID COAL-BASED FERTILIZER PLANT AT TALCHER - - - - - - - - - 42

VISITORS - - - - - - - - - - - 42

STAFF MATTERS - - - - - - - 43

OBITUARY - - - - - - - - - - 44
(Dr N. R. Kuloor)

CFRI ABSTRACTS - - - - - - 45

The Problem of Coking Coal

THE limited reserves of good coking coal compared to the large deposits of high quality iron ore occurring in India have been a matter of concern to the planners and the public alike. The problem was again highlighted in a recent Symposium, held at the CFRI, on "Problem of Coking Coal" organized by the Mining, Geological & Metallurgical Institute of India and the Joint Working Committee of the three Coal Mining Associations of India. All aspects of production, conservation, distribution, beneficiation and utilization of coking coals were discussed. We present a summary of the papers presented in the Symposium in this issue. The Chief Guest Mr K. K. Ray, Chairman, Coal Board, stressed the need of conserving the prime coking coals by resorting to blending medium and weakly coking coals, a field in which major contributions have been made by CFRI over the past years. He also discussed the measures that could be taken in mining to reduce the losses, such as by open-cut mining, stowing of thick seams and by controlled caving by French technique recently tried by the NCDC at Gidi. The key-note of his address was, however, on the urgency of long term planning. It is in this context that we publish in this issue the paper presented by Dr A. Lahiri, Director, CFRI, on "Demand, Reserves and Planned Production of Coking Coals in India".

The life of reserves of coking coals, obviously, depends upon (a) the actual annual demand of coking coal over a period of years, which in turn depends on planned production of iron and steel; (b) losses in preparation; and (c) losses in mining. The paper is notable for its depth of study into the problem. Dr Lahiri has estimated the probable demand of iron and steel for the next three decades by various methods of projection. Taking all factors into consideration he has estimated that with an average of 6 per cent per annum increase in hot metal production (starting from base of 12 million tonnes per annum by 1971), the country will need about 65 million tonnes per annum by the end of the century and this will be supplemented by an additional 10 per cent of hot

(*Continued on p.* 38)

DEMAND, RESERVES AND PLANNED PRODUCTION OF COKING COAL IN INDIA*

COKING and blendable coals are required for making metallurgical coke primarily for iron and steel and allied industries including foundries. We have, therefore, at the first instance, considered three expected rates of growth of production of iron and steel and arrived at a reasonable estimate of hot metal production during the next three decades, viz. from 1970-71 to 2000/2001 A.D. In assuming the future rate of growth of iron and steel we have been mainly guided by the fact that the internationally recognized norms of economic growth, viz. National Income (or Gross National Product), index of industrial production, consumption *per capita* of energy or steel, etc., in respect of any individual country or a group of countries are highly correlated. Fig. 1 depicts such a correlation between GNP, energy consumption and steel consumption *per capita* in respect of some developed countries and India which is at the lowest rung of the ladder.

Demand of Coking Coal

The three different bases of estimation of future hot metal production are as follows.

The first basis (Basis I) assumes a compound growth rate for hot metal production: 6 per cent for the first decade from 1971-80, 7 per cent for the following decade and 7·5 per cent for the third decade from 1991 to 2000 A.D. The actual rate of growth of hot metal production in India during 1961-68 has been 7·25 per cent. According to this method of estimation, hot metal production may rise from 12 million tonnes in 1971 to 81 million tonnes by 2000 A.D.

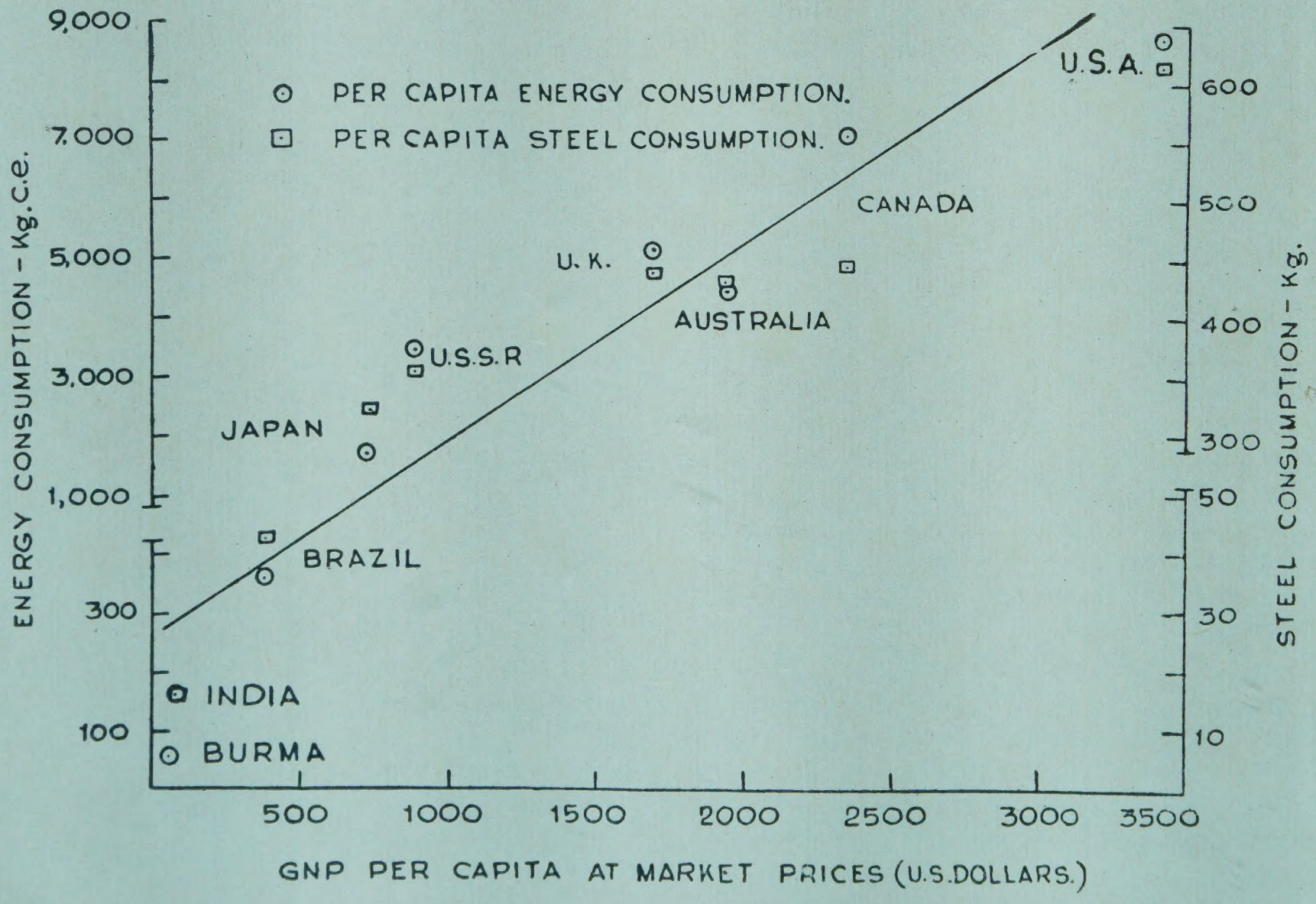


FIG. 1 — PER CAPITA NATIONAL INCOME, ENERGY CONSUMPTION AND STEEL CONSUMPTION FOR SOME COUNTRIES (1966)

*Reproduced with the approval of the Symposium Committee.

TABLE 1 — TOTAL AND *PER CAPITA* PRODUCTION OF HOT METAL IN INDIA

Year	Estimated population (million)	Estimated production of hot metal (million tonnes)			Per capita production of hot metal (kg.)		
		Basis I	Basis II	Basis III	Basis I	Basis II	Basis III
1971	544	12·0	12·0	9·6	22·0	22·0	17·6
1976	606	16·0	16·0	14·9	26·4	26·4	24·6
1981	676	21·5	21·5	19·6	31·8	31·8	29·0
1986	746	29·3	28·6	24·2	39·3	38·3	32·4
1991	824	42·0	38·4	28·9	51·0	46·6	35·1
1996	887	60·0	51·3	33·5	67·6	57·8	37·8
2000	955	81·0	64·8	38·1	84·8	67·9	39·9

Note — Actual 1968 — 15 kg/cap.
Cf. Japan 1966 — 330 kg/cap.

The second basis (Basis II) assumes a constant growth rate of 6 per cent per annum in line with the post planning average industrial growth in India. The estimated hot metal production according to this method is 12 million tonnes in 1971 and 65 million tonnes in 2000 A.D.

In the third basis of estimation (Basis III), a regression equation has been derived from the data on actual and target production of hot metal over the period 1967-68 to 1973-74. This regression equation has been utilized in projecting the future production. The equation is $H_t = 7{\cdot}46 + 0{\cdot}93t$, where H_t = hot metal production in million tonnes during tth year with $t = 0$ in 1967-68.

Thus the first basis leads to a figure of 81 million tonnes, second yields a figure of 65 million tonnes and the third 38 million tonnes of hot metal by 2000 A.D. Table 1 sets out the figures of estimated population, hot metal production (total and *per capita*) every 5 years during 1971-2000 A.D. The estimation of future population has been made on the assumption that the growth rate will fall from 2·2 per cent per annum to 1·8 per cent per annum by the end of the century. The *per capita* steel production may be compared to that of Japan during 1966 according to which even the first basis of estimation does not seem to be very ambitious.

Estimations of coking coal requirement for stipulated hot metal production were made on the following assumptions.

(i) *Broad classification of Indian coking and blendable coals on the basis of the volatile matter and coking propensities* — Coals for coking can be divided into three Groups A, B and C mainly on the basis of their volatile matter and coking properties. Group A coals include all the coking coals of Jharia field with strongly coking propensities. Group B represents mainly the medium volatile coking coals of East and West Bokaro fields along with coals of Laikdih group of seams of Raniganj field, while the high volatile caking coals mainly Dishergarh seam (Raniganj) may be classified as Group C coals.

(ii) *Coke rate* — Strenuous efforts are being made in all steel producing countries for improvement in metal production per unit volume of blast furnace and reduction of coke rate[1,2]. To what extent the coke rate can be reduced will depend on the one hand on (a) the extent of pretreatment of the ore, e.g. ore beneficiation; (b) use of self-fluxing sinter and pellets and the extent to which pre-reduced ore, especially pellets are used and on the other the extent to which coke as a source of heat energy, as distinct from its role as a reductant, is replaced by other types of fuels such as high b.t.u. gas, oil, or even coal, or coal-oil slurry and blast furnace design and management. In practice, the coke consumption varies between 0·6 and 1·0 t/t depending on the above conditions.

As against the current consumption of coke of 0·90 tonne per tonne of hot metal (a ratio expected to remain largely unchanged up to 1975), a fall to 0·855 has been allowed for up to 1980 and 0·810 from 1981-90 and 0·765 from that year till 2000 A.D. These reductions in coke consumption have been presumed on the expectation that, gradually, during the next three decades, partial replacement of coke by

oil, increased use of self-fluxing sinter and pellets and finally use of pre-reduced pellets will be effected. A certain amount of iron will also be produced by electric smelting for special purposes. In areas away from coking coal sources but occurring in the neighbourhood of non-coking coal areas or sources of oil and gas, there will be greater replacement of coke than in coalfield based steel plants. It is expected that special techniques such as are currently being developed for production of 'formed coke'[1,3] from non-coking coals will also be introduced, thus lowering the total requirement of coking coals.

(iii) *Yield of clean coal and blending* — India possesses over two-thirds of the world's high grade iron ore reserves, but the quality as well as the quantity of coking coal likely to become available are low. With regard to quality, even after beneficiation, it is hardly possible to produce a coke with less than 22-24 per cent ash and this too often after sacrifice of nearly 50 per cent of the raw coal during beneficiation[4].

Since nearly 1·5 tonnes of coal is required for a tonne of useable coke for blast furnace, in India about 3 tonnes of raw coal have to be processed to get this amount, the recovery of clean coals currently in use varies between 70 and 50 per cent. As the extraction of coal is roughly between 50 and 60 per cent of the *in situ* reserves, every tonne of coke used involves exhaustion of nearly 6 tonnes of *in situ* reserves. It is, therefore, incumbent, in view of the admittedly low reserves of coking coal suitable for metallurgical purposes, that all attempts be made to reduce coke consumption in blast furnace and also conserve metallurgical coal by making use of other coals in blends so that the life of the resources can be extended.

During the past decades and a half, through extensive researches[5-7] carried out at the CFRI and at the CBCR laboratory (jointly operated by CSIR and TISCO), supported by commercial scale testing, it has been established that 50-60 per cent of the prime coking coal can be replaced by medium and blendable coking coals, provided adequate facilities for blending and equipment for preparation including selective crushing, exist and correct type of coke ovens and operating conditions are used in practice. In a recent joint meeting of all steel plant authorities and the coal and steel planning authorities, the CFRI formula[8] of 50: 40: 10 for prime: medium: blendable coking and caking coals has been, by and large, accepted. We feel that this can be substantially improved upon with greater attention to production and preparation of coals.

However, in assessing the requirements of coking coal for future, an assumption is made that these blend proportions will be largely followed in spirit and in practice by all steel plants both in public and private sectors. Their ability to use such blends in practice will in turn depend on the nature of equipment and facilities provided. These do not exist today and the need for provision of such facilities is so overwhelming that compulsion is not only justified but is unavoidable.

The assumption regarding the blend made here is important as this enables the life of the reserves to be extended by more than 100 per cent. In calculation of the future requirements of the quantity and types of coals, this assumption has been followed. Coal quality will deteriorate with exhaustion of the better grades of coals and some deterioration in yield of clean coal on beneficiation has been allowed for. Finally, technological improvements leading to progressively lower rates of coke consumption has also been taken into consideration.

For Group A coking coals we have assumed yield of clean coal to an extent of 60 per cent up to 1975-76 and 50 per cent thereafter, for Group B coking coals the yield of clean coal has been taken as 50 per cent during the entire period of 1971-2000 A.D. Group C caking coal will not be washed.

(iv) *Blast furnace coke and yield of coke in coke ovens* — Blast furnace coke: 85 per cent of run-of-oven coke of size +37 mm are expected to be used in blast furnace up to 1975 after which coke of lower size up to 20 mm (90 per cent of run-of-oven coke) would be used. Yield of run-of-oven coke will be 75 per cent of the coking blend charged to coke ovens.

Estimated production of hot metal and requirements of all types of coals as assessed by the three bases are shown in Table 2 and Figs. 2, 3(a) and 3(b). For further discussion, basis II has only been considered. Table 3 shows the estimated requirements of coal according to basis II allowing for technological improvements in the next three decades. It is seen that for about

p

D BLENDABLE COAL (AS MINED) BY STEEL PLANTS

TED REQUIREMENTS OF COKING AND BLENDABLE COAL WITH REDUCTION IN COKE RATE FROM 0·900 t/t TO 0·765 t/t (million tonnes as mined)

	Basis I			Basis II				Basis III			
	Grp. B	Grp. C	Total	Grp. A	Grp. B	Grp. C	Total	Grp. A	Grp. B	Grp. C	Total
1	13·5	1·7	29·3	14·1	13·4	1·7	29·2	11·3	10·8	1·4	23·5
1	16·2	2·0	38·5	20·3	16·2	2·0	38·5	18·5	14·8	1·9	35·2
1	20·6	2·6	49·0	25·7	20·6	2·6	48·9	23·5	18·8	2·4	44·7
1	28·1	3·5	66·8	34·4	27·6	3·4	65·4	29·0	23·2	2·9	55·1
1	38·1	4·8	90·5	43·6	34·8	4·4	82·8	32·8	26·2	3·3	62·3
1	54·4	6·8	129·2	58·1	46·4	5·8	110·3	38·0	30·4	3·8	72·2
2	73·5	9·2	174·5	73·5	58·8	7·4	139·7	43·2	34·6	4·3	82·1

er annum between 1991 and 2000 A.D.

gression formula: Hot metal (mt) = 7·46+0·93 t (t = 0 in 1967-68).

1976 to 1980; 0·81 t/t from 1981 to 1990; and 0·765 t/t from 1991 to 2000 A.D.

coke: 75% of coal charged.

he entire period.

als.

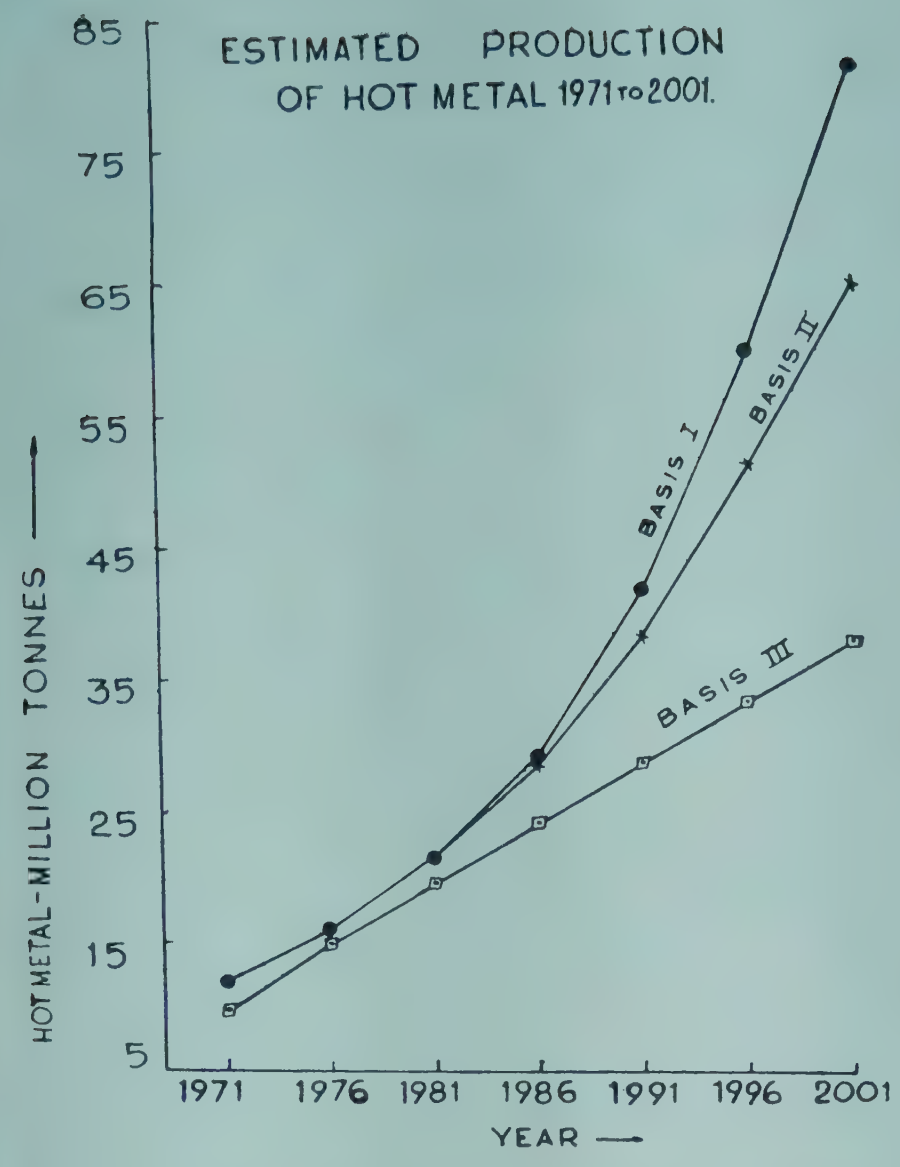


FIG. 2 — ESTIMATED PRODUCTION OF HOT METAL 1971-2001 A.D.

65 million tonnes of iron production in 2000 A.D. nearly 140 million tonnes of raw coal will be required for beneficiation and coking. To this has to be added the requirement of coal for merchant ovens for foundry coke. This is included in Table 4 and Fig. 4.

Table 4 further indicates that the requirement of prime coking coals (Group A) will increase from approximately 14 million tonnes in 1971 to about 86·5 million tonnes in the next 30 years. Similarly, the requirements of medium coking coals (Group B) will be about 69 million tonnes and blendable coals (Group C) about 9 million tonnes, making up a total of about 165 million tonnes per annum. Fig. 4 indicates the annual requirement of the three classes of coal for the next three decades.

Without the availability of prime coking coals, much of the reserves of medium and blendable coking coals will be of no avail. Hence, it is especially important to assess the minimum requirement and available reserves of Group A, viz. prime coking coal.

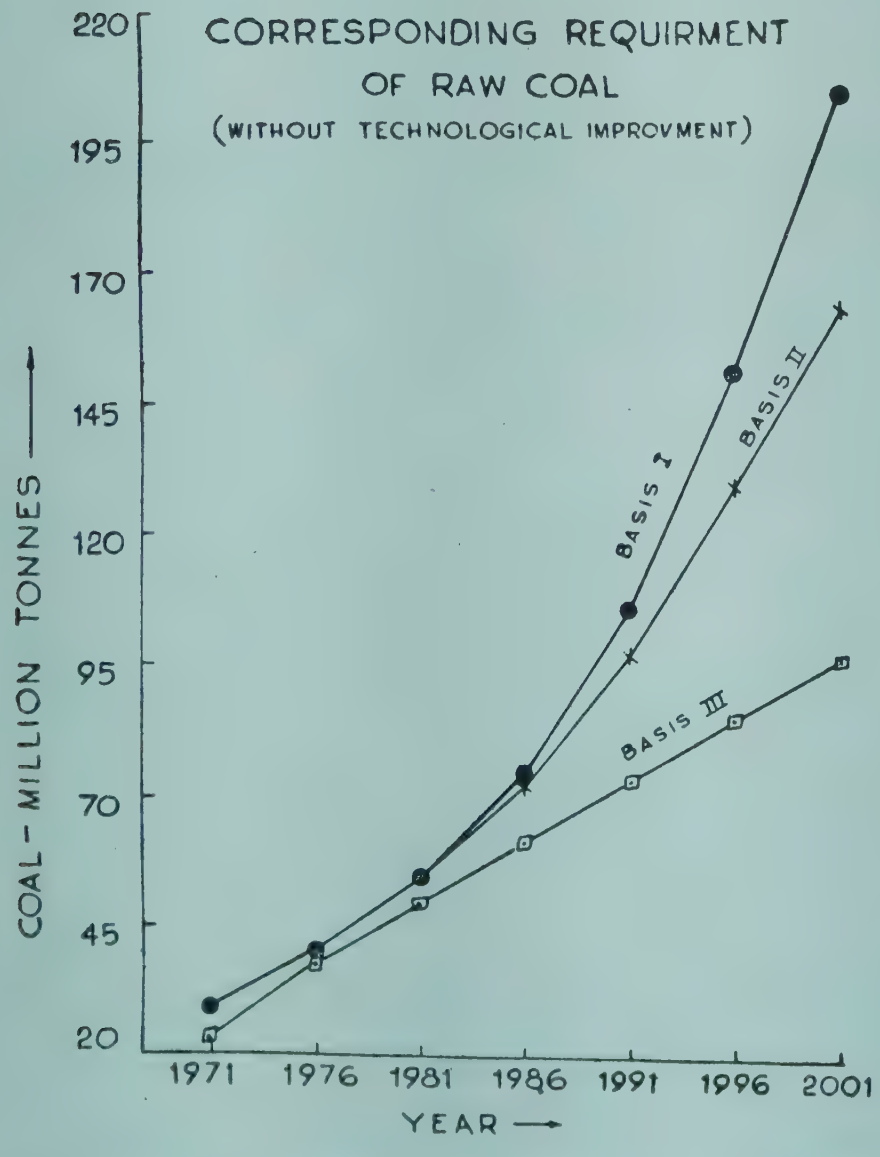


FIG. 3(a) — CORRESPONDING REQUIREMENT OF RAW COAL (WITHOUT TECHNOLOGICAL IMPROVEMENT)

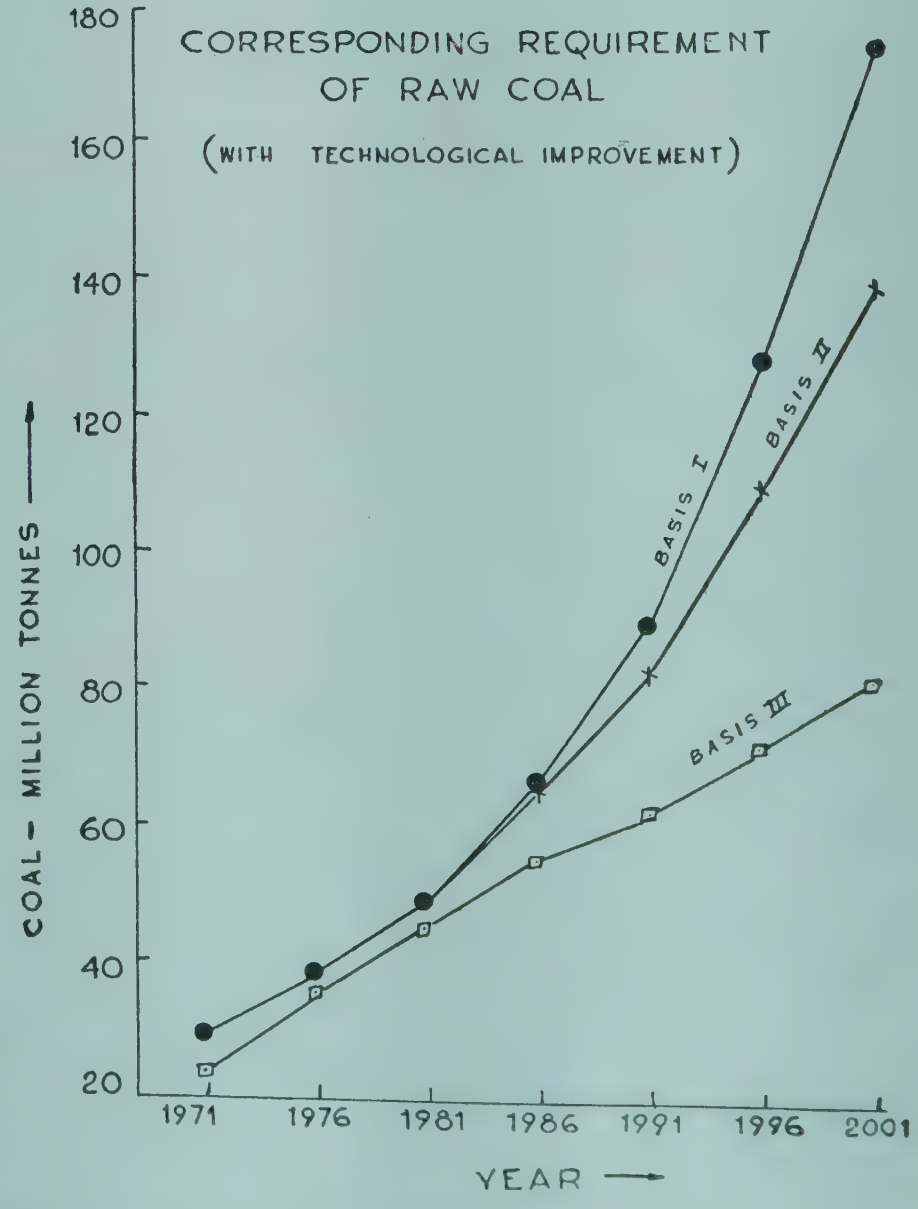


FIG. 3(b) — CORRESPONDING REQUIREMENT OF RAW COAL (WITH TECHNOLOGICAL IMPROVEMENT)

TABLE 3 — ESTIMATED REQUIREMENTS OF COKING AND BLENDABLE COALS FOR IRON & STEEL INDUSTRY (1971-2000 A.D.)

BASIS II

Year	Estimated hot metal production (m. tonnes)	Requirement of sized coke (m. tonnes)	Requirement of run-of-oven coke (m. tonnes)	Requirement of coals as charged to coke ovens				Requirement of raw coal, million tonnes			
				Total	Grp. A (50% of total)	Grp. B (40% of total)	Grp. C (10% of total)	Grp. A	Grp. B	Grp. C	Total
1971	12·0	10·8	12·7	16·9	8·5	6·7	1·7	14·2	13·4	1·7	29·3
1976	16·0	13·7	15·2	20·3	10·2	8·1	2·0	20·3	16·2	2·0	38·5
1981	21·5	17·4	19·3	25·7	12·9	10·3	2·6	25·7	20·6	2·6	48·9
1986	28·6	23·2	25·8	34·4	17·2	13·8	3·4	34·4	27·6	3·4	65·4
1991	38·4	29·4	32·7	43·6	21·8	17·4	4·4	43·6	34·8	4·4	82·8
1996	51·3	39·2	43·6	58·1	29·1	23·2	5·8	58·1	46·4	5·8	110·3
2000/1	64·8	49·6	55·1	73·5	36·8	29·4	7·4	73·5	58·8	7·4	139·7

Note — (i) Production of hot metal is assumed to rise by 6% per annum.

(ii) Coke rate will be 0·90 t/t up to 1975, 0·855 t/t from 1976 to 1980, 0·810 t/t from 1981 to 1990, and 0·765 from 1991 to 2000 A.D.

(iii) 85% of the run-of-oven coke will be used in blast furnace up to 1975 and 90% thereafter, size of b.f. coke: +37 mm. up to 1975, +20 mm. thereafter.

(iv) Recovery of cleans in washeries for Grp. A coals will be 60% up to 1975 and 50% thereafter. For Grp. B coals: 50% over the entire period; Grp. C coals will be used raw, i.e. will not be washed.

TABLE 4 — ESTIMATED RAW COKING AND BLENDABLE COALS FOR IRON & STEEL, FOUNDRIES AND ALLIED INDUSTRIES DURING 1971-2001 A.D.

Year	Iron & steel indusiry*				Foundry and allied industry**				Iron & steel, foundries and allied industries			
	Requirement of Raw Coal for Hot Metal Production (million tonnes)				Requirement of Raw Coal for Allied Industry (million tonnes)				Requirement of Raw Coal (million tonnes)			
	Grp. A	Grp. B	Grp. C	Total	Grp. A	Grp. B	Grp. C	Total	Grp. A	Grp. B	Grp. C	Total
1971	14·2	13·4	1·7	29·3	2·2	0·7	0·3	3·2	16·4	14·1	2·0	32·5
1976	20·3	16·2	2·0	38·5	3·5	1·0	0·4	4·9	23·8	17·2	2·4	43·4
1981	25·8	20·6	2·6	49·0	4·1	3·3	0·5	7·9	29·9	23·9	3·1	56·9
1986	34·4	27·6	3·4	65·4	5·4	4·4	0·7	10·5	39·8	32·0	4·1	75·9
1991	43·6	34·8	4·4	82·8	7·2	5·7	1·0	13·9	50·8	40·5	5·4	96·7
1996	58·1	46·4	5·8	110·3	9·7	7·8	1·3	18·8	67·8	54·2	7·1	129·1
2001	73·5	58·8	7·4	139·7	12·9	10·4	1·7	25·0	86·4	69·2	9·1	164·7

*(i) Production of hot metal is estimated on the basis of 6% per annum increase (Basis II).

(ii) Coke rate assumed at (a) 0·900 t/t up to 1975, (b) 0·855 t/t for 1976-80, (c) 0·810 t/t for 1981-90, and (d) 0·765 t/t thereafter, blast furnace coke: +37 mm up to 1975 and +20 mm. thereafter.

(iii) The proportion of blend is expected to be A: B: C = 50: 40: 10.

(iv) Grps. A and B coals will be washed: Recovery of clean for Grp. A coals is assumed to be 60% up to 1975 and 50% thereafter. For Grp. B coals it will be 50% over the whole period.

**(i) 10% of the hot metal production will be used in pig iron foundries and sized coke (+100 mm.) requirements per tonne of pig is 0·25 t.

(ii) Additional requirements for steel foundries, general engineering, chemical, etc., are also taken into consideration.

(iii) The rate of coal requirements as charged to ovens also comes to about 6% per annum.

(iv) For 1971-76 blend composition A: B: C = 70: 20: 10, after 1976 — A: B: C = 50: 40: 10.

(v) Washed coal requirements: 1971 — 10% for both Grps. A and B coals; 1976 — 25% for both Grps. A and B; 1976 onwards — 50% of both Grps. A and B coals.

TABLE 5 — REQUIREMENT AND RATE OF EXHAUSTION OF COKING AND BLENDABLE COALS FOR IRON & STEEL, FOUNDRIES AND ALLIED INDUSTRIES (1971-2000 A.D.)

Year	Requirement of coal as charged to ovens									Production requirements (requirements of raw coal)			Cumulative requirements of coals for iron and steel and allied industries [ref. Table 3 (million tonnes)]			Exhaustion of *in situ* reserve		
	Iron & Steel Industry*			Foundries and Allied Industries**			Total											
	Grp. A	Grp. B	Grp. C	Grp. A	Grp. B	Grp. C	Grp. A	Grp. B	Grp. C	Grp. A	Grp. B	Grp. C	Grp. A	Grp. B	Grp. C	Grp. A	Grp. B	Grp. C
1971	8·5	6·7	1·7	2·1	0·6	0·3	10·6	7·3	2·0	16·4	14·1	2·0	16·4	14·1	2·0	32·8	28·2	4·0
1976	10·2	8·1	2·0	2·8	0·8	0·4	13·0	8·9	2·4	23·8	17·2	2·4	116·8	97·4	13·6	233·6	194·8	27·2
1981	12·9	10·3	2·6	2·7	2·2	0·5	15·6	12·5	3·1	29·9	23·9	3·1	256·0	204·4	27·9	512·0	408·8	55·8
1986	17·2	13·8	3·4	3·6	2·9	0·7	20·8	16·7	4·1	39·8	32·0	4·1	433·9	346·4	46·3	867·8	692·8	92·6
1991	21·8	17·4	4·4	4·8	3·8	1·0	26·6	21·2	5·4	50·8	40·5	5·4	668·8	534·3	71·0	1337·6	1068·6	142·0
1996	29·1	23·2	5·8	6·5	5·1	1·3	35·6	28·3	7·1	67·8	54·2	7·1	970·6	775·9	102·7	1941·2	1551·8	205·4
2000	36·8	29·4	7·4	8·6	6·9	1·7	45·4	36·3	9·1	86·4	69·2	9·1	1296·7	1037·0	137·2	2593·4	2074·0	274·4

*(i) Production of hot metal is estimated on the basis of 6% per annum increase (ref. Basis II).

(ii) Coke rate assumed at (a) 0·900 t/t up to 1975, (b) 0·855 t/t for 1976-80, (c) 0·810 t/t for 1981-90 and, (d) 0·765 t/t thereafter.

(iii) The proportion of blend is expected to be A: B: C = 50: 40: 10.

(iv) Grps. A and B coals will be washed: Recovery of clean for Grp. A coals is assumed to be 60% up to 1975 and 50% thereafter, for Group B coals it will be 50% over the whole period.

**(i) 10% of the hot metal production will be used in pig iron foundries and sized coke (+100 mm.) requirements per tonne of pig is 0·25 t.

(ii) Additional requirements for steel foundries, general engineering, chemicals, etc., are also taken into consideration.

(iii) The rate of coal requirements as charged to ovens also comes to about 6% per annum.

(iv) For 1971-76 blend composition A: B: C = 70: 20: 10 after 1976; A: B: C = 50: 40: 10.

(v) Washed coal requirments: 1971 — 10% for both Grps. A and B coals; 1976 — 25% for both Grps. A and B; 1976 onwards — 50% for both Grps. A and B coals.

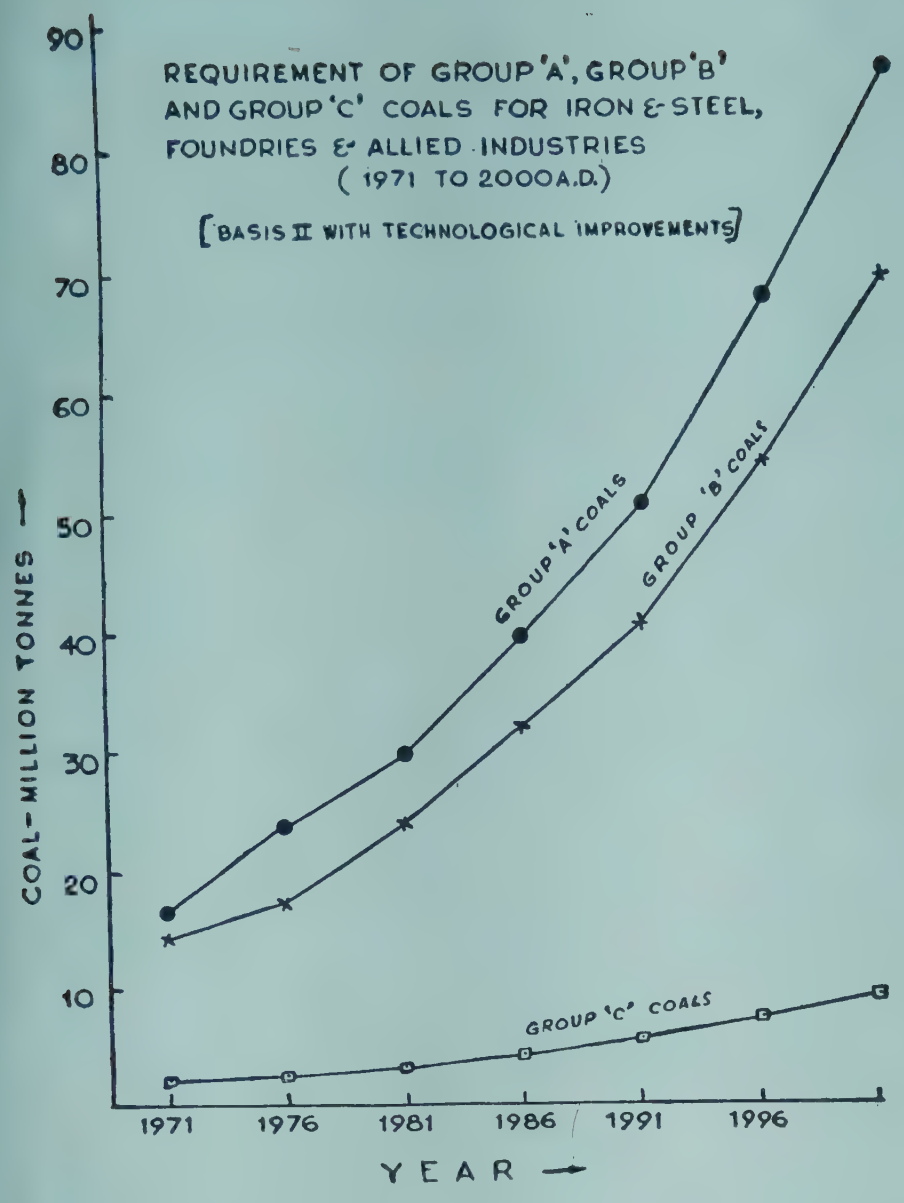


FIG. 4 — REQUIREMENT OF GROUPS 'A', 'B' AND 'C' COALS FOR IRON AND STEEL, FOUNDRIES AND ALLIED INDUSTRIES (1971-2000 A.D.)

Figures for cumulative use of the different classes of coking coal reserves are given in Table 5. Assuming 50 per cent extraction of *in situ* reserves by 2000 A.D., it is expected to exhaust 2600 million tonnes of prime coking coals (Group A), 2074 million tonnes of medium coking coals (Group B) and 274 million tonnes of blendable coals (Group C). Thus the total 'exhaustion' of *in situ* reserves of prime and medium coking coals will be of the order of 4670 million tonnes as against the *in situ* reserves of 11,500 million tonnes. Of course, the extraction rate can be improved by various methods.

Group A Coals

The overall gross reserves[9] of the Barakar Measure coals (IX-XVIII seams) from the coking coal seams of Jharia field is of the order of 6000 million tonnes up to a depth of 609 m (Table 6). But, unfortunately, the whole of 6000 million tonnes are not suitable for coke making. From tests carried out with coals being produced at various depths, as well as tests on borehole coal cores, it has been assessed that coals with a volatile matter below 22 per cent (pure coal basis) will not be suitable for coking, though in certain areas coals in the upper seams with about 20 per cent volatile matter indicated some possibility of coke making[10]. In the seams below XIII, 22 per cent volatile matter (on pure coal basis) can be taken as the limit. In making the calculation of the reserves, projections have been made on the basis of the availability of the coal in the light of their metamorphism at depths.

Of the 18 coal seams of this field, normally only the seams IX and above are considered suitable as prime coking coals. Coals suitable for coking, be it at shallow or at greater depths, are largely located in the eastern half of Jharia field, east of Kirkend. The reserves of coking coals in the lower seams (IX-XII) suitable for coking on the western half of the Jharia field is limited by the decrease in volatile matter. Reserves of these seams having volatile matter below 22 per cent have not been included. In the eastern half, even seams lower than IX have indicated good potentials for

TABLE 6 — JHARIA COALFIELD: RESERVE OF SEAMS UP TO A DEPTH OF 609 METRES

SEAMS	RESERVE IN MILLION TONNES
I	407
II	1160
III	698
IV & II/III/IV	1204
V	1058
VI	330
VII	157
V/VI/VII/VIII	1308
VIII	383
VIIIA	226
IX	454
X & IX/X	1284
XI	485
XI/XII	242
XII	381
XIII	520
XIIIA	9
XIIIB	30
XIV	534
XIVA	35
XV	442
XVA	63
XVI	284
XVIA	120
XVII	241
XVIII	111

TABLE 7 — RESERVE OF COALS FOR COKING

Particulars	Gross reserves (in million tonnes) Rg	Extractable reserves (in million tonnes) Re
1. *Group A Coals*		
I. *Class 1 — Jharia Coalfield*		
(a) IX-XVIII seams (less 339 m. of unleased area)	4261	2102
(b) Prospecting Blocks of NCDC* (Kapuria, Monidih, Jarma, Parbatpur, Sudamdih) (less reserves in leased areas of 165 metres)	984	740
II. *Class II — Jharia Coalfield* V-VIII A seam (approx.)	520	260
	5765	3102
2. *Group B Coals*		
(A) *Raniganj Coalfield*		
(i) Chanch-Begunia-Ramnagar-Laikdih seams	769	
(ii) Shampur-Chatabar basin coals	129	
	898	478
(B) *East Bokaro Coalfield*		
(i) Kargali-Kathara-Sawang group and Jarangdih group of seams	2036	1213
(ii) Bermo-Karo group of seams	2011	1168
	4047	2381
(C) *West Bokaro Coalfield** V, VI, VII seams in Loiyo Taping, Kedla Blocks and Ghato area	373	186
(D) *Ramgarh Coalfield** VI, VII Top and Bottom and VIII A seam, Block 1	61	30
(E) *Kanhan Valley Coalfield** Main seam	100	50
(F) *Jharia Coalfield, Raniganj Measures* Mohuda group of seams	282	246
Total of Group B coals	5761	3371
3. *Group C Coals*		
I. Class I (Semi-coking, High Volatile)		
(A) *Raniganj Coalfield*		
(i) Dishergarh Sanctoria seam	443	239
(ii) Kasta seam (Pariarpur Arang sector)	80	196
(iii) Burra Dhemo-Raghunathbatty-Hatnal seams	270	
(B) *Ramgarh Coalfield** VI, VIIA, VII Top and Bottom and VIII seams, Block II	178	89
(C) *West Bokaro Coalfield** V, VI, VII seams, Pundi Block	121	60
	1092	584
II. Class II (Caking, High Volatile)		
(A) *Raniganj Coalfield* Poniati-Koithee seam	1024	582
(B) *Sohagpur Coalfield** V-Seam, Churcha-Jhilimili area	40	20
(C) *Jharia Coalfield* (Caking, Low Volatile)		
(i) I-IV seam	3469	1735
(ii) V-VIIIA seam west of Kirkend	1304	652
Total of Group C coals	6929	3573

Note — 1. Extractable reserves — After allowing for locked up coals, losses for geological disturbance and mining losses.

*Figures taken from various reports of the respective prospecting blocks, etc. For Parbatpur Block, 706 million tonnes up to 800 metres and other blocks up to 600 metres. Other data taken from Coal Assessment Sub-Committee Report 1964.

coking (seams V-VIII) and have been added to the reserves[11]. Thus, out of over 1800 million tonnes of coal *in situ* in the V-VIII seams, about 520 million tonnes will be available as coking coals, confined to the eastern half. But, in the eastern half, even the major coking coal seams between IX and XII will not be suitable for coking below 600 m depth due to loss of volatiles.

Group B coals

Of the medium coking coals, the most attractive reserves are in the Kargali group of seams in the East Bokaro coalfield, which have more than 2000 million tonnes of *in situ* reserves[9]. Almost an equal quantity is in the Lower Seams (Bermo-Karo group), but the beneficiation characteristics of these coals are rather poor, thus restricting availability. The major part of the remainder, i.e. nearly 900 million tonnes occur in the Raniganj coalfield. The rest is spread out in the seams of the Raniganj measures in the Jharia coalfield, some in West Bokaro, and Ramgarh coalfields, and a small amount in the Kanhan Valley (M.P.).

The *in situ* reserves of coking coals in Groups A and B are roughly equal, viz. about 5800 million tonnes for Group A and 5800 million tonnes for Group B (Table 7).

Group C Coals

Compared to A and B groups, the reserves of Group C or the blendable coals, the quality of which varies from immature high volatile to overmature low volatile coals, are not only higher but are also widely dispersed in the Bengal-Bihar-M.P. coalfields. The reserves are nearly 7000 million tonnes taking all qualities of coal including those at depth up to 600 metres (Table 7).

The Dishergarh group of seams[12] and Poniati group to some extent are the most valuable of the Group C coals due to their low ash and highly caking nature which allows their use in blends up to 30-40 per cent even by current coke oven technology. They are especially valuable as matching coals for the very low volatile coals in the Jharia coalfield with which they make excellent metallurgical coke. In these respects, they can, for utility purposes, be grouped with Group A coals. These coals are now largely used for steam raising.

The extractable reserves of the above *in situ* reserves are, however, considerably lower. A large amount of coal to the tune of 900 m. tonnes is locked up[9] in barriers between existing fragmented properties and under surface structures, especially railway tracks and roads in the coalfields. Some reserves are also locked up between mining panels due to the present method of mining. Others are unavailable as barriers for fire areas and surface properties, e.g. houses and buildings. The total coal unavailable in these may be well over 15 per cent of *in situ* reserves. Selective mining and other losses in mining may account for another 35 per cent. There is a distinct possibility of eliminating such waste, but meanwhile a figure of only 50 per cent of *in situ* reserves has been assumed as extractable reserves.

From coals that are mined, we have to subtract the losses in beneficiation to arrive at figures for 'available reserves' of coal for coking. According to present-day practice, the ratio of *in situ* to available reserves is 4:1. Undoubtedly the ratio can be improved upon by careful planning and substantial investment.

The above analysis shows that given due attention to technology and compulsory blending and with conservation of prime coking coals, the rate of production of iron that will be reached by 2000 A.D., viz. about 65 million tonnes per year, can be maintained, perhaps for another 50 years.

As against the requirement of 1100 million tonnes of prime coking coals in the next 30 years for hot metal production, the extractable reserves are of the order of 3000 million tonnes. Therefore, by 2000 A.D. about $\frac{1}{3}$ of the extractable prime coking coals will be used up on the basis of this calculation. Thus, even for the requirement of hot metal by Basis I, the reserves are sufficient for the next 80 years or so. On the other hand, if reliance were to be placed on prime coking coals alone, then the life of reserves may not even extend beyond the present century. In that case, perhaps not more than 25 million tonnes/year of iron production by current technology will be possible.

There should be no undue optimism about current blast furnace technology being replaced by other techniques of steel making in the near future. All authorities agree that for the next 50 years or more, blast furnace iron will be the major source of metal for the world, though other techniques on a smaller scale may come into operation. This, however, should not deter us from actively pursuing methods for production of iron with coking coal. Used judiciously and with continuous straining towards technological improvements, both in ore and in coal and coke preparation, India's reserves of coals for coking should

be adequate for 75-80 years provided the reserves are exploited in a planned manner, conserved and rationally utilized.

Conservation and Planned Production of Prime Coking Coals

The foregoing have sufficiently indicated the importance of the prime coking coals of Group A, the reserves of which are almost entirely confined to the Jharia coalfield. This coalfield has been exploited for nearly 80 years and due to unscientific mining in the past, a good quantity of this coal has already been wasted.

The coal seams of Jharia coalfield are numbered from I to XVIII. The lower seams occur at the bottom and have low volatile matter. The coal seams in general dip from north to south indicating that the same seam would occur at progressively greater depths in the south than in the north. Lower the depth the lower is also the volatile matter. As indicated earlier, a volatile matter of less than 22 per cent is unsuitable for use as prime coking coal. There is also a lateral variation of volatile matter from west to east. As a rule the volatile matter of a particular seam is higher in the eastern part of the field (east of Kirkend) compared to that in the western part for the same depths, e.g. IX/X seams in the western part has a volatile matter of 22 per cent at a depth of 150 m. only compared to the 22 per cent at 600 m. depth in the east. Thus, areas east of Kirkend have higher volatile matter than the west for the same seam at the same depth. Through detailed survey carried out by the CFRI and its Coal Survey Laboratories, it has been possible to prepare 'iso-volatile' lines for IX/X seam and XV seam to give an idea of the useful areas for coking coal (Plate I). These studies show that, by and large, coals below IX/X seam are unsuitable for use as prime coking coal except in the eastern sector where V-VIII seams also have now been found to be suitable for coking up to a depth of about 300 m.

Thus, for all intents and purposes, the outcrop of IX/X seams in the north can be taken as the northern limit of the prime coking coals, except east of Kirkend. The large number of small mines occurring north of the outcrop of IX/X seam is of less interest (northern zone) from the point

TABLE 8 — STRUCTURE OF COKING COAL MINES IN INDIA (1968)

Monthly output of mines (tonnes)	Jharia		Raniganj		Bokaro	
	Number	Production/month (tonnes)	Number	Production/month (tonnes)	Number	Production/month (tonnes)
Up to 1000	18 (17%)	2900 (0·3%)	—	—	8 (53·3%)	—
1001 to 5000	35 (33%)	95,000 (10·0%)	—	—	—	—
5001 to 10,000	15 (14%)	106,200 (11·0%)	2 (33·3%)	19,900 (27·8%)	1 (6·7%)	900 (4%)
10,001 to 25,000	28 (27%)	424,500 (45·0%)	4 (66·7%)	51,600 (72·2%)	3 (20·0%)	60,000 (24%)
25,001 to 50,000	9 (9%)	317,300 (33·7%)	—	—	2 (13·3%)	69,300 (29%)
More than 50,000	—	—	—	—	1 (6·7%)	104,100 (43%)
Total	105 (100%)	945,900 (100%)	6 (100%)	71,500 (100%)	15 (100%)	242,400 (100%)

Note — The figures of quantity of coal produced/month includes some quantity of non-coking coals also.

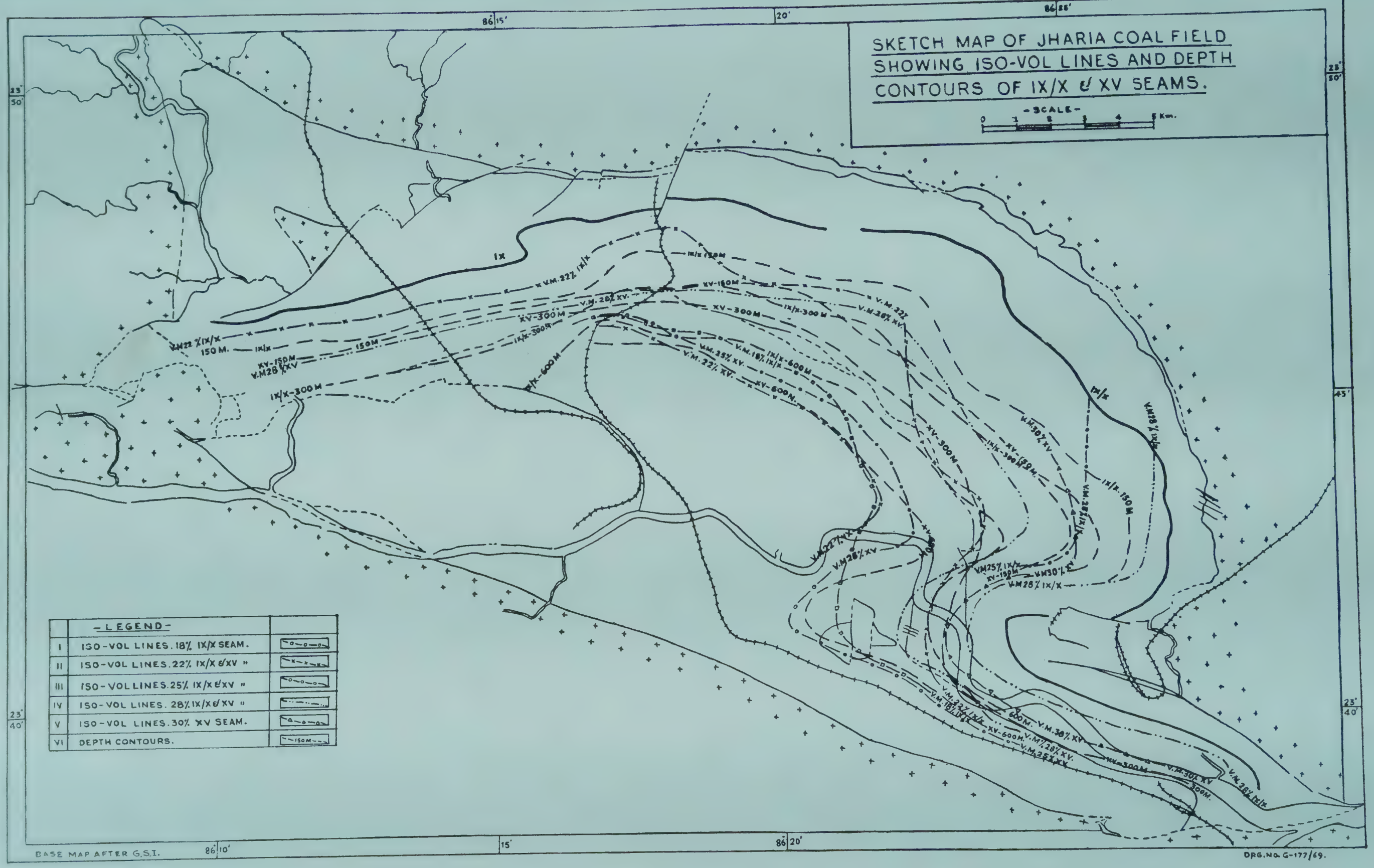


PLATE I — SKETCH MAP OF JHARIA COALFIELD SHOWING ISO-VOL LINES AND DEPTH CONTOURS OF IX/X AND XV SEAMS

TABLE 9 — RESERVEWISE CLASSIFICATION OF PRIVATE SECTOR COLLIERIES

Classes of reserves (million tonnes)	No. of collieries
1. Less than 1	16
2. 1-2·5	21
3. 2·5-5	18
4. 5-10	26
5. 10-25	22
6. 25-50	23
7. 50-100	6
8. More than 100	9
	141

of view of organized production of prime coking coal and are excluded.

Areas lying south of this line and up to almost the contact of Barakar/Barren measures constitute the middle zone. This area is roughly covered by the 600 m. depth line of IX/X seam. This zone contains all the working collieries of prime coking coal which are all owned by private companies. There are about 140 producing units in this area. A large number of these producing units are very small with meagre reserves and low production. Of course, there are some big producing units with some substantial reserves. The reserve and productionwise classification of these collieries are shown in Tables 8 and 9. The total production from this zone is about 11·2 million tonnes with a total reserves of about 4200 million tonnes.

But none of these individual units (except a few) is big enough either from the point of view of production or reserves to maintain an economic washing unit of its own. Most of these units have low reserves and are naturally incapable of increasing their production substantially. Others having fair quantity of reserve may not have sufficient financial resources to raise the production to the extent of running a viable washing unit. Only a few collieries owned by big companies are in a position to do so. Thus it becomes essential, for any substantial increase in production of prime coking coals to reorganize these small collieries into viable producing units with substantial reserves and production.

In the south of this middle zone, lying over the barren measures, NCDC have acquired large areas which were so long virgin. Seams occurring in this zone are at depths and the useful reserves are limited both by depth and by loss of volatile matter with increasing depth. A number of good coal seams have been completely or partially burnt due to igneous intrusions. NCDC collieries hold a total reserve of 1100 million tonnes, with a present production of only 0·036 m. tonnes and a targeted production of 4·2 m. tonnes.

The upper seam coals (XIII-XVIII) containing more than 25 per cent V.M. are more important from the point of view of coking. They can also accommodate greater proportion of medium coking and blendable coals. The upper seams have on the whole easier beneficiation characteristics. If the propertywise distribution of the coals having volatiles above 25 per cent are considered (Table 10), then the public sector possesses nearly 1000 million tonnes compared to about 1500 million tonnes in the private sector.

Nearly 2200 million tonnes of coals from IX to XII seams occur in the private sector distributed between the big and small collieries. Hence from the point of view of future production, major reserves of coking coals lie within the private sector; the more easily mineable reserves being held by the comparatively smaller collieries. The reserves of lower seams suitable for coking are less than 100 million tonnes in the public sector that too lying at great depths.

The major reserves of coking coal in the Jharia coalfield occur in IX-XII seam, the total reserve of these seams being 3700 million tonnes out of 6000 million tonnes. Thus lower seams at depth will largely represent the future reserves of coking coals which are at present mined

TABLE 10 — CLASSIFICATION OF RESERVES OF COAL FOR COKING IN THE WORKING SEAMS OF DIFFERENT SECTORS ACCORDING TO VOLATILE CONTENT

Particulars	Reserves in million tonnes		Total
	Volatile Matter on Unit Coal Basis		
	Less than 25%	More than 25%	
Private sector	1868	1523	3391
Public sector	136	964	1100

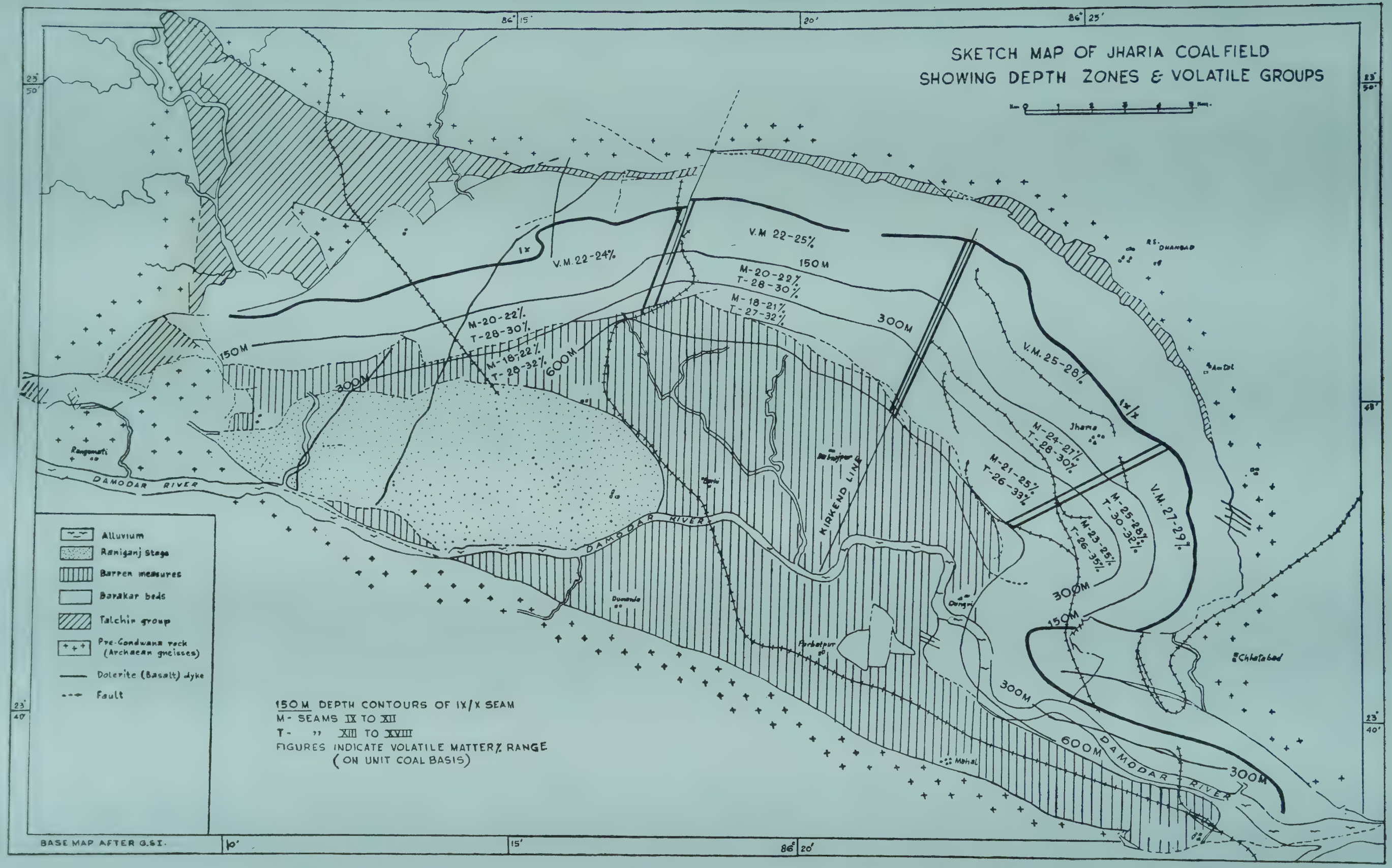


PLATE II — SKETCH MAP OF JHARIA COALFIELD SHOWING DEPTH ZONES AND VOLATILE GROUPS

in relatively low proportions by private sector. The contrary is the case at shallow depths in the outcrop region of IX-XII seams, except in the area east of Kirkend where upper seams are exploited more.

Due to exhaustion of better classes of coking coal, currently more than 90 per cent or more of coal used for steel plants require beneficiation. Efficient beneficiation involves operation of large multi-unit washing plants having capacities of 400-500 tonnes/hour. Presently, operation of such plant involves supply of coals from a large number of small mines. This naturally involves lot of double handling of the raw coal. Apart from considerable problems of transport of coal from large number of scattered mines all over the field (often from neighbouring coalfields), uncertain production and still more uncertain quality of coals delivered to the washeries have also resulted in serious losses in production capacity and in recovery of clean coals as well as middlings.

The washeries normally should produce coals of a given quality, this means that the supplies must be drawn from limited areas (both laterally and vertically) so that the variation in coal properties not only for ash but for volatiles and other coke making properties are minimized and controlled to give a consistent quality. The only way of achieving this technically desirable end could be to divide and demarcate Jharia coalfield in blocks following the 'isovol' lines and limiting the production between certain depths and seams in variable blocks having sufficient reserves. Depthwise extension of blocks perhaps may conveniently be limited to 150 metres from surface, 150-300, 300-600 and 600-900 metres. The quality of coals from the upper group of seams (XIII-XVIII) and lower group of seams (IX-XII) would be of fairly consistent in quality as regard coking properties as well as ash within such depth zones. In the light of the above, the Jharia field may be divided into separate depth zones (depth contour line of IX/X seam, Plate II). Since the isovol lines of seams are more or less parallel to depth contours, the division of the field into four sectors, divided into four zones as indicated above on the basis of depth, will produce coals of coking qualities of narrow ranges, more so when divided into the lower and upper group of seams.

References

1. Lahiri, A., "Conservation of Metallurgical Coal and Production of Fluxed-Ash Formed Coke from Non-coking Coals for Iron & Steel Industry", I.I.M. and I.L.F.A. Symposium on Economics of Installation and Operation of Steel Plants in Developing Countries, Calcutta, 1968.
2. Dastur, M. N. *et al.*, "Blast Furnace Productivity and Costs", I.I.M. and I.L.F.A. Symposium on Economics of Installation and Operation of Steel Plants in Developing Countries, Calcutta, 1968.
3. CFRI Formed Coke Process Brochure, 1967.
4. Lahiri, A. *et al.*, "Problems of Cleaning of Indian Coals and Rational Use of Products from Coal Beneficiation", VII World Power Conf., Moscow, 1968.
5. CFRI Metallurgical Coke from Raniganj Coals, 1955.
6. Das Gupta, N. N. *et al.*, "Pilot Plant Studies on the Production of Metallurgical Coke", Proc. N.M.L. Symp. on Pilot Plants in Metal Ref. and Dev., 1960.
7. CBCR, Jamshedpur, Annual Reports 1963-66.
8. CFRI Final Report on the Rational and Equitable Distribution of Coking and Blendable Coals to the Steel Plants during the IV Plan Period, 1969.
9. Comm. on Assess. of Resources — Coal Resources of Jharia, Raniganj and East Bokaro Coalfields, 1967.
10. CFRI Annual Report of Jharia Coal Survey Laboratory, 1965.
11. CFRI Jharia Coal Survey Laboratory Tech. Rep. No. 1, 1965.
12. CFRI Unpublished Monograph on Dishergarh Seam.

SELECTION OF COKING BLEND FOR THE ROURKELA STEEL PLANT

THE biggest steel producer in India, the Hindustan Steel Ltd. (formed in 1954 in the Public Sector), ranking twenty-fifth among the largest steel producers of the world, has three steel plants located at Rourkela, Bhilai and Durgapur. With the completion of ex pansion programmes of the steel plants in public and private sectors and the starting up of Bokaro Steel Plant, the annual production of hot metal will be about 13 million tonnes by the end of the fourth Five Year Plan. The requirement of coal as charged to the oven for the production of this quantity of hot metal will be about 19 m. tonnes.

Rourkela Steel Plant with a production target of 1·7 million tonnes of hot metal by the end of the Fourth Plan will require about 2·4 million tonnes of coal as charged to the oven by 1973-74. Supply of this quantity of coal cannot be maintained from the existing sources, as parts of these coals have to be allotted to other steel plants in order to make a rational distribution of coking coals. Investigations were, therefore, undertaken at the Central Fuel Research Institute to study the possibility of incorporating, in blends, coals from newer sources of the Jharia and Bokaro-Ramgarh-Karanpura coalfields. The present communication deals with the coking tests done with washed coals from Dugda II, Bhojudih, Sawang and Bhurkunda/ Gidi coals for selecting a suitable blend for the coke ovens of Rourkela Steel Plant.

Earlier Work at CFRI

The coke ovens of the Rourkela Steel Plant in the earlier stages of their operation carbonized a binary blend consisting of 25-40 per cent washed Dugda I coal and 60-75 per cent washed Kargali coal. This blend was selected after extensive tests carried out at CFRI. Later on, about 10-15 per cent of high volatile Dishergarh seam coal of Raniganj coalfield was incorporated in the coking mixture. Further tests done at CFRI in 1965-66 showed the possibility of effecting considerable savings by using Churcha V seam coal of Jhilmili coalfield (M.P.) in the coking blend to the extent of 10-15 per cent by replacing the coal of Dishergarh seam.

Coal Samples and Their Characteristics

Coals from the following sources were used for the series of coking tests carried out in 1968:

(i) Raw coal mixture of Dugda II schedule coals was constituted as follows:

XI seam, Sijua area	12·3%
X seam, Sijua and Katras area	36·8%
IX seam, Katras area	11·9%
VII seam, Katras area	19·0%
V special seam, Katras area	20·0%

(ii) Washed Bhojudih coal from Bhojudih washery.

(iii) Sawang coal (mixture of Kargali top and bottom, 7 ft. and 12 ft. seams).

(iv) Gidi-Bhurkunda, Argada/Sirka seam coals.

Originally, HSL desired the tests to be conducted with Dugda II, Sudamdih, Sawang, and Gidi washed coals. But Bhojudih washed coal was used as a substitute of Sudamdih coal as the particular seams of Sudamdih colliery (NCDC) which are to supply coal beyond 1970 were not yet in production. Dugda II, Sawang and Gidi/Bhurkunda coals were washed in the CFRI pilot coal washing plant before conducting the coking tests.

Properties of individual coals used for different coking tests are shown in Tables 1 and 2. Dugda II and Bhojudih washed coals are coking coals from the Jharia coalfield, of which the former being derived from the lower seams, is maturer than the latter as evidenced by the lower volatile matter and higher carbon contents on pure coal basis. However, Dugda II washed coal is of inferior coking characteristics compared to Bhojudih washed coal as shown by swelling index, LT GK coke type and plastic properties. The Sawang coal from East Bokaro coalfield is a high volatile coal of medium coking properties and can be blended in substantial proportions with good coking coals for the production of metallurgical coke. The washed coal from

TABLE 1 — RESULTS OF PROXIMATE ANALYSIS, CAKING INDEX, SWELLING INDEX AND GIESELER'S TEST OF INDIVIDUAL COALS

Sl No.	Particulars of coals	Proximate analysis (air-dried basis) %				V.M. d.m.f. basis %	C.I.	S.I.	Gieseler's test		LT GK coke type	ISI coal code
		M	A	V.M.	F.C.				Max. Fluidity, dial div./min.	Plastic Range °C.		
1	(W) Dugda II	0·9	17·0	19·3	62·8	21·9	21	3½	235	55	E/F	862/852
2	(W) Bhojudih	1·1	16·9	25·0	57·0	29·0	25	6½	>2000	—	G_3	745
3	(W) Sawang	1·1	15·0	29·4	54·5	33·9	22	4	>2000	—	G_1	734
4	(W) Gidi/Bhurkunda	3·8	15·1	31·7	49·4	37·9	10	1	3·7	—	C	421

(W) — Washed coal.

TABLE 2 — RESULTS OF ULTIMATE ANALYSIS, ASH FUSION RANGE, PETROGRAPHIC ANALYSIS AND H.G.I. OF INDIVIDUAL COALS

Sl No.	Particulars of coals	Ultimate analysis (d.m.f. basis) %					Ash fusion range		Petrographic analysis % vol (visible mineral-free basis)			HGI
		C	H	S	N	O (by diff.)	Initial Deformation temp. °C.	Hemispherical temp. °C.	Vitrinite	Exinite	Inertinite	
1	(W) Dugda II	91·0	4·9	0·6	1·8	1·7	1140	>1400	54·2	0·4	45·4	80
2	(W) Bhojudih	90·6	4·9	0·6	2·0	1·9	1030	1280	68·3	0·9	30·8	76
3	(W) Sawang	88·7	5·3	0·8	1·7	3·5	1115	>1400	54·7	8·4	36·9	55
4	(W) Gidi/Bhurkunda	84·4	5·3	0·6	1·7	8·0	1160	>1400	57·5	6·2	36·3	54

Argada-Sirka seams of the South Karanpura coalfield is a weakly coking coal of lower rank which can only be incorporated in smaller proportions in coking blends.

Petrographic analysis given in Table 2 is characterized by high inertinite content in case of Dugda II, and high vitrinite content in case of Bhojudih coals. The exinite contents of these two coals are much lower than Sawang and Argada-Sirka coals.

Preparation of Charge for Coking

Tests were conducted with coals crushed to two different fineness, 75-80 per cent through 3 mm. and 100 per cent through 3 mm. Fineness of 75-80 per cent through 3 mm. was achieved by using 7 mm. screen on the screen deck and recycling the oversize till it passed through the screen. A 3 mm. screen was used to achieve a fineness of 100 per cent through 3 mm. For the preparation of blends, the individual coals were first crushed to the desired fineness and kept in separate bunkers and later blended in required proportions in a mixer with addition of water for adjustment of gross moisture in the blend to the desired level.

Carbonizing Conditions

All the test charges excepting stamped one were carbonized in the 400 mm. pilot oven of CFRI at flue temperatures of 1240-60°C. Pilot plant tests on portions of blend prepared for large scale test were, however, conducted in 450 mm. oven at about 1210°C. flue temperature in order to obtain data comparable to those from large scale test carried out in the commercial oven at TISCO. Gross moisture of the pilot plant coking tests was maintained at 5-6 per cent for top charges and 10 per cent for the stamped charge.

Tests on Straight Coals

Coking tests were conducted in the 400 mm. oven on the following straight coals (Table 3) under the specified carbonizing conditions mentioned earlier:

(i) Raw and washed Dugda II schedule coals.
(ii) Washed coal from Bhojudih washery.
(iii) Raw and washed Sawang coal.

Carbonization of washed Dugda II coal and washed coal from Bhojudih washery produced excellent metallurgical coke.

TABLE 3 — RESULTS OF COKING TESTS DONE ON STRAIGHT COALS

Sl No.	Particulars of the charge	Per cent of the charge	Fineness of the charge % through 3 mm.	Mean particle size of the charge mm.	G.M. %	B.D. of the charge in the oven kg/m.³ (dry)	Coke yield % (dry basis)	Mean size of the coke mm.	Physical properties of Coke: Micum Index On 40 mm.	Micum Index Through 10 mm.	Shatter Index On 38 mm.	Shatter Index On 13 mm.	Haven Stability Factor on 25 mm.	Porosity %
1	(R) Dugda II	100	75-80	1·83	6·0	888	80·6	111·0	75·9	19·0	93·8	96·1	46·9	41·2
2	(W) Dugda II	100	75-80	2·32	5·0	856	79·6	94·5	79·0	10·0	92·9	98·0	59·5	41·2
3	(W) Dugda II	100	100	—	5·0	833	—	98·6	78·0	11·2	92·2	97·9	59·7	—
4	(W) Bhojudih	100	75-80	1·54	5·6	824	75·9	85·1	74·8	10·2	91·0	97·6	50·7	44·8
5	(W) Bhojudih	100	100	—	6·3	787	—	81·5	78·7	10·3	91·3	97·7	50·9	48·9
6	(R) Sawang	100	75-80	2·03	5·2	820	73·4	106·7	76·2	15·5	93·2	96·6	42·6	47·6
7	(W) Sawang	100	75-80	2·27	4·3	823	72·5	83·3	71·9	14·0	89·3	98·5	52·7	47·8
8	(W) Sawang	100	100	0·90	5·4	791	72·1	75·2	73·6	12·3	86·6	97·5	57·9	47·6

However, coke produced from washed Sawang coal was sub-standard in physical strength. Raw Dugda II and Sawang coals gave relatively abradable cokes due to higher mineral matter compared to those obtained from the respective washed coals. All the three washed coals on finer crushing produced coke of improved physical properties.

Tests on Blends with Coarse Crushing

In all, 11 blends were carbonized in the 400 mm. oven. This included one ternary and 10 quarternary blends. Table 4 shows the results of coking tests done on these blends.

Excellent metallurgical coke was produced from the ternary blend of Dugda II, Bhojudih and Sawang washed coals in the proportion of 40 : 32·5 : 27·5. Tests done with quarternary blends containing 10 per cent washed Gidi/Bhurkunda coal along with varying proportions of (W) Dugda II, (W) Bhojudih and (W) Sawang coals show that for obtaining a satisfactory coke with constituent coals crushed to a fineness of 75-80 per cent through 3 mm., the minimum proportion of prime coking coals (Dugda II and Bhojudih washed coals) in the blend should be 70 per cent. Decrease in proportions of prime coking coals in the blend below 70 per cent makes the coke sub-standard in physical strength. Quarternary blend consisting of 40 per cent (W) Dugda II, 30 per cent (W) Bhojudih, 20 per cent (W) Sawang and 10 per cent (W) Gidi/Bhurkunda coals produced satisfactory coke.

To find out the extent of improvement in physical properties, three of the cokes were also tested after dropping twice from a height of 2 metres. Marked improvement in the micum indices of coke after dropping was observed in all the three cases compared to the ex-wharf coke. The results of tests on these partially stabilized cokes have been shown below those of ex-wharf cokes for comparison.

Tests on Blends with Fine Crushing

Eight coking tests were done after crushing the constituent coals selectively to pass 100 per cent through 3 mm. This also included one stamped charging test. Table 5 shows the results of these coking tests.

Blend containing even 60 per cent prime coking coals, 30 per cent (W) Sawang and 10 per cent (W) Gidi/Bhurkunda coals did not produce metallurgical coke even though the constituent coals were crushed selectively to pass 100 per cent, through 3 mm. For producing metallurgical coke, a minimum proportion of 65 per cent prime coking coals was found necessary with fine crushing of the constituent coals. The proportion of prime coking coals could be brought down to even 50 per cent and the proportion of weakly coking (W) Gidi/Bhurkunda coal could be increased up to 25 per cent in the blend to produce metallurgical coke when all the coals were selectively crushed to pass 100 per cent through 3 mm. and the blend was stamp charged.

The coke produced from the blend containing Dugda II, Bhojudih, Sawang and Gidi/Bhurkunda washed coals in proportion of 40 : 30 : 20 : 10 was also dropped twice from a height of 2 metres and was found to show remarkable improvement in physical strength compared to the ex-wharf coke.

Commercial Scale Test

For confirming the results of pilot plant tests, the following blend was prepared for conducting a full scale test in a commercial oven of TISCO at Jamshedpur:

Blend		
(W) Dugda II	40%	All coals were crushed about 75% through 3 mm.
(W) Bhojudih	30%	
(W) Sawang	20%	
(W) Gidi/Bhurkunda	10%	

The coke produced from the commercial oven was tested at Jamshedpur and also a part of the coke was brought in a truck to CFRI for tests. Results of the commercial scale coking test done at Jamshedpur and the corresponding three pilot plant tests done at CFRI on the same blend are shown in Table 6.

Coke produced from all the three pilot plant tests had satisfactory physical strength. Due to unavoidable circumstances, the prepared large scale blend had to be stored for nearly three weeks before the commercial scale test could be conducted. It was probably oxidized to some extent as evidenced by the decrease of maximum fluidity (Gieseler's test) from 155 dial div./min.

TABLE 4 — RESULTS OF COKING TESTS DONE ON BLENDS WITH COARSE CRUSHING

Sl No.	Particulars of the charge	Per cent	Fineness of the charge % through 3 mm.	Mean particle size of the charge mm.	G.M. %	B.D. of the charge in the oven kg/m.³ (dry)	Coke yield % (dry basis)	Mean size of the coke mm.	Physical properties of coke					Porosity %
									Micum Index		Shatter Index		Haven Stability Factor on 25 mm.	
									On 40 mm.	Through 10 mm.	On 38 mm.	On 13 mm.		
1	(W) Dugda II	40	All 75-80	1·95	5·6	833	76·8	93·0	76·9	11·7	93·2	97·7	55·1	47·5
	(W) Bhojudih	32·5												
	(W) Sawang	27·5												
2	(W) Dugda II	25	75-80	1·76	5·8	827	75·4	105·7	74·5	12·5	93·3	97·4	51·7	47·6
	(W) Bhojudih	35												
	(W) Sawang	30												
	(W) Gidi/Bhurkunda	10												
3	(W) Dugda II	25	75-80	2·08	6·0	841	75·4	95·8	76·4	11·8	92·4	97·8	50·8	46·0
	(W) Bhojudih	35						—	*78·2	11·3	94·0	97·7	51·1	
	(W) Sawang	30												
	(W) Gidi/Bhurkunda	10												
4	(W) Dugda II	35	75-80	1·84	6·0	813	76·0	89·9	74·6	12·4	92·4	97·5	52·8	43·9
	(W) Bhojudih	30												
	(W) Sawang	25												
	(W) Gidi/Bhurkunda	10												
5	(W) Dugda II	35	75-80	1·84	5·5	810	76·0	85·6	73·3	13·3	90·5	97·0	50·3	45·9
	(W) Bhojudih	30												
	(W) Sawang	25												
	(W) Gidi/Bhurkunda	10												
6	(W) Dugda II	35	75-80	1·84	5·1	813	76·0	92·5	76·4	12·6	91·4	96·9	53·2	46·0
	(W) Bhojudih	30						*69·3	79·6	11·0	94·2	98·2	52·2	
	(W) Sawang	25												
	(W) Gidi/Bhurkunda	10												
7	(W) Dugda II	40	75-80	1·92	5·2	836	76·9	90·9	75·9	12·2	91·5	97·7	54·9	45·4
	(W) Bhojudih	30												
	(W) Sawang	20												
	(W) Gidi/Bhurkunda	10												
8	(W) Dugda II	40	75-80	1·86	5·5	803	76·6	90·9	75·8	12·5	90·5	97·4	54·5	39·1
	(W) Bhojudih	30						*74·7	78·7	11·2	94·2	98·2	51·1	
	(W) Sawang	20												
	(W) Gidi/Bhurkunda	10												
9	(W) Dugda II	40	75-80	1·81	6·0	817	76·0	89·8	76·7	12·6	92·8	97·0	50·9	46·4
	(W) Bhojudih	30												
	(W) Sawang	20												
	(W) Gidi/Bhurkunda	10												
10	(W) Dugda II	45	75-80	1·87	5·0	830	76·4	95·5	75·2	12·8	92·1	96·6	50·0	49·2
	(W) Bhojudih	25												
	(W) Sawang	20												
	(W) Gidi/Bhurkunda	10												
11	(W) Dugda II	45	75-80	2·39	5·6	822	76·0	102·9	74·5	13·6	92·2	97·0	52·6	45·1
	(W) Bhojudih	20												
	(W) Sawang	25												
	(W) Gidi/Bhurkunda	10												

*Results of tests done after dropping the coke twice from a height of 2 metres.

TABLE 5 — RESULTS OF COKING TESTS DONB ON BLENDS WITH FINE CRUSHING

Sl No.	Particulars of the charge	Per cent	Fineness of the charge % through 3 mm.	Mean particle size of the charge mm.	G.M. %	B.D. of the charge in the oven kg/m.³ (dry)	Coke yield % (dry basis)	Mean size of the coke mm.	Physical properties of coke					Porosity %
									Micum Index		Shatter Index		Haven Stability Factor on 25 mm.	
									On 40 mm.	Through 10 mm.	On 38 mm.	On 13 mm.		
1	(W) Dugda II	25	All	1·11	5·4	—	75·9	86·4	74·1	12·1	88·7	97·0	51·7	47·7
	(W) Bhojudih	35												
	(W) Sawang	30	100											
	(W) Gidi/Bhurkunda	10												
2	(W) Dugda II	35												
	(W) Bhojudih	30												
	(W) Sawang	25	100	1·07	5·9	803	76·0	83·1	75·9	11·5	91·1	97·5	57·4	—
	(W) Gidi/Bhurkunda (with 0·5% oil)	10												
3	(W) Dugda II	40												
	(W) Bhojudih	30	100	1·07	5·9	796	76·1	89·2	76·1	12·0	91·5	96·9	56·1	—
	(W) Sawang	20												
	(W) Gidi/Bhurkunda	10												
4	(W) Dugda II	40												
	(W) Bhojudih	30	100	1·03	5·5	816	76·4	86·4	77·0	11·0	91·7	97·4	57·8	42·8
	(W) Sawang	20						*65·3	81·4	9·5	94·4	98·0	57·9	
	(W) Gidi/Bhurkunda (with 0·5% oil)	10												
5	(W) Dugda II	45												
	(W) Bhojudih	25	100	1·13	5·5	788	76·7	85·1	77·7	11·7	91·7	97·7	50·6	45·1
	(W) Sawang	20												
	(W) Gidi/Bhurkunda	10												
6	(W) Dugda II	45												
	(W) Bhojudih	20	100	1·08	5·7	795	76·8	86·9	76·8	12·2	90·3	96·6	53·5	43·3
	(W) Sawang	25												
	(w) Gidi/Bhurkunda	10												
7	(W) Dugda II	45												
	(W) Bhojudih	20												
	(W) Sawang	25	100	1·32	6·0	805	76·7	86·1	76·1	11·9	91·6	97·6	60·3	46·3
	(W) Gidi/Bhurkunda (With 0·5% oil)	10												
8	(W) Dugda II	25												
	(W) Bhojudih	25												
	(W) Sawang	25	100	1·28	10·0	†997	75·3	96·5	79·6	13·1	92·6	96·6	56·8	—
	(W) Gidi/Bhurkunda (Stamped charge)	25												

*Results of tests done after dropping the coke twice from a height of 2 metres.
†B.D. of stamped cake.

TABLE 6 — RESULTS OF COMMERCIAL SCALE TEST AND THE CORRESPONDING PILOT PLANT TESTS

Sl No.	Test	Particulars of the charge	Per cent	Fineness % through 3 mm.	Mean particle size of the coal charge mm.	G.M. %	Mean size of the coke mm.	Physical properties of coke					Porosity %
								Micum Index		Shatter Index		Haven Stability Factor % on 25 mm.	
								On 40 mm.	Through 10 mm.	On 38 mm.	On 13 mm.		
1	Large scale test done at TISCO, Jamshedpur, after 3 weeks of preparation of the blend	(W) Dugda II	40	All 75-80	2·23	3·3	—	74·8*	14·6	92·3	96·6	44·3	48·8
		(W) Bhojudih	30				—	77·0†	13·9	94·0	97·7	—	
		(W) Sawang	20				95·2	79·6‡	11·5	94·0	97·9	53·7	
		(W) Gidi/Bhurkunda	10				78·5	81·9§	10·5	94·9	99·0	56·0	
2	Pilot plant test done at CFRI simultaneously with the large scale test at Jamshedpur	(W) Dugda II	40	75-80	2·24	3·0	103·9	78·7	12·3	93·8	97·9	55·1	42·6
		(W) Bhojudih	30										
		(W) Sawang	20										
		(W) Gidi/Bhurkunda	10										
3	Pilot plant test done after 5 days of preparation of the large scale blend	(W) Dugda II	40	75-80	2·24	4·6	112·0	80·1	12·1	94·3	98·4	54·6	45·5
		(W) Bhojudih	30										
		(W) Sawang	20										
		(W) Gidi/Bhurkunda	10										
4	Pilot plant test done with fresh coals	(W) Dugda II	40	75-80	1·92	5·2	90·9	75·9	12·2	91·5	97·7	54·9	45·4
		(W) Bhojudih	30										
		(W) Sawang	20										
		(W) Gidi/Bhurkunda	10										

*Results of ex-wharf coke tested at Jamshedpur.
†Results of tests done at Jamshedpur after dropping the coke twice from a height of 2 metres.
‡Results of tests done (without drop) at CFRI on the large scale test coke transported to CFRI in a truck.
§Results of tests done at CFRI after dropping the coke twice from a height of 2 metres.

to 66 dial div./min. Slightly sub-standard coke was, therefore, produced with M_{40} and M_{10} indices of 74·3 and 14·6 respectively. This coke, however, improved to the metallurgical standard after it was dropped twice from a height of 2 metres. Sample of the coke (large scale test) brought from TISCO to CFRI in truck got somewhat stabilized during transit and hence showed much improved physical strength. Tests done at CFRI showed the coke to have M_{40} and M_{10} indices of 79·6 and 11·5 respectively. Further stabilization of this coke by dropping twice from a height of 2 metres effected further improvement in the physical properties.

Summary and Recommendations

(1) On straight carbonization, (W) Dugda II and (W) Bhojudih coals produced excellent metallurgical coke. However, coke produced from 100 per cent Sawang coal was sub-standard in physical strength.

(2) Coke of metallurgical standard can be produced from a ternary blend consisting of 40 per cent (W) Dugda II, 32·5 per cent (W) Bhojudih and 27·5per cent (W) Sawang coals.

(3) For the production of standard metallurgical coke from a quarternary blend containing 10 per cent (W) Gidi/Bhurkunda coal, the minimum proportion of prime-coking coals (Dugda II and Bhojudih washed coals) in the blend should be 70 per cent if the constituent coals are crushed 75-80 per cent through 3 mm.

(4) If the coals are crushed 100 per cent minus 3 mm. and 0·5 per cent of oil is added to the blend, then the proportion of prime-coking coals can be safely reduced to 65 per cent and that of (W) Gidi/Bhurkunda coal can still be kept at 10 per cent in the blend for production of metallurgical coke of good quality. Addition of this small quantity of oil will help in increasing the bulk density of the charge in the oven improving the flow characteristics of the blend and in the production of coke of more uniform size and quality. The addition of oil is, in general, beneficial to plant operation.

(5) The proportion of prime-coking coals in the blend can be brought down to even 50 per cent and the proportion of weakly coking (W) Gidi/Bhurkunda coal can be increased up to 25 per cent provided all the coals are crushed selectively to pass 100 per cent through 3 mm. and the blend is stamp charged.

M. V. P. Menon, K. Singh,
K. Raja, S. Biswas,
N. G. Banerjee
& A. K. Moitra

PROBLEMS OF COKING COAL—A SYMPOSIUM

THE third in the series of six Symposia on Coal Mining Industry — Its Perspective and Problems being organized by the Mining, Geological and Metallurgical Institute of India (MGMI) and the Joint Working Committee (JWC) of Indian Mining Association, Indian Mining Federation, Indian Colliery Owners' Association and M.P. and Vidarbha Mining Association with the co sponsorship of Coal Board, the Institute of Engineers (India), National Coal Development Corporation Ltd. and Hindustan Steel, was held at Central Fuel Research Institute, Dhanbad, on 14 and 15 February 1970. The symposium comprising four sessions, discussed in detail the Problems of Coking Coals — Its Production, Conservation, Distribution, Beneficiation and Utilization. Mr R. N. Sharma, Chairman, Dhanbad Sub-Committee, while introducing the Chief Guest, Mr K. K. Ray, Coal Controller, mentioned in brief the scope and usefulness of the symposium. He also pointed out the appropriateness of holding such a symposium in the context of the prevailing problems of coking coal supply. He hoped that such a forum would help solving to a great extent problems such as stagnancy of production, productivity, control of fires, conservation, stowing, beneficiation, quality control, distribution, prices and profits.

Extending a hearty welcome to the participants of the symposium, Mr R. G. Deo, Chairman, Coal Symposium Committee, said that the obligation of satisfying the needs of coking coal of the consuming industries rested on the producers and the snags in this direction could only be solved by mutual exchange of views of emiment experts in this line at such meetings.

In his speech, Mr K. K. Ray, Guest-in-Chief, spoke of the blending of coal and highly appreciated the work of CFRI on selection of coal blends for different steel plants with the ultimate object of reducing the content of coking coal in the mixture and thus conserving it.

Referring to possible shortage of sand for stowing, Mr Ray apprised the gathering of the endeavours of various authorities towards relieving the problems of sand. He focused attention on the decision of the government to promote opencast mining and the willigness of the Coal Board to give substantial subsidy in this direction. He also pointed out that efforts were being made by the Coal Board to invite 'Sofremines' — the leading French Consultants — who would test the suitability of 'caving-in' method for extraction of coal from the Jharia coalfield.

Referring to the opinion in favour of export of coal on the ground of continued accumulation of coal at mine site, Mr Ray said that such accumulation was of temporary nature and the long term interest of the country should not be sacrificed for short term gains for a handful of persons.

First Session

The session dealt with the production aspect of coking coal under the Chairmanship of Shri I. M. Thapar. In his speech, Shri Thapar presented a brief account of the reserves, production and the growing demand of coking coal. Considering the existing and future bottlenecks of the industry, he contended that increased production might seem to be an impossible task, but a dynamic and pragmatic approach in the appropriate time and direction might bring about the resurrection of the industry. Shri Thapar highlighted the importance of 'Formed Coke' in this context and expressed his profound appreciation for the work in this line undertaken at CFRI. He appreciated the decision of the Committee in selecting CFRI as the venue of this symposium, considering the services rendered by this Institute for the development of coal industry. He held high hopes that the Institute would continue to resolve the problems facing this industry.

The following papers were presented and taken up for discussion: (1) Demand, Reserves and Planned Production of Coking Coal in India by A. Lahiri, Director, CFRI, and (2) Problems of Coking Coal Production by J. R. Sharma and H. K. Banerjee, Bhowrah Kankanee Collieries Ltd.

Dr Lahiri presented three bases of calculating future hot metal production. In one, assuming an average growth rate of 6 per cent/annum, he showed that by 2000 A.D. the production target would possibly reach a figure of 65 million tonnes/annum

for which 86·4 million tonnes of Group A coals (strongly coking coals of Jharia field), 69·2 million tonnes of Group B coals (medium volatile coking coals) and 8·6 million tonnes of Group C coals (high volatile caking coals) would be required. The other assumptions made here were: (i) coke rate would remain constant at 0·9 tonne/tonne of hot metal, (ii) yield of run-of-oven coke would be 75 per cent of coal charged, (iii) 85 per cent up to 1975 and 90 per cent thereafter of the run of oven coke would be used as blast furnace coke, and (iv) the yield of clean coal from group A would be 60 per cent up to 1975 and 50 per cent thereafter, for group B coals it would be 50 per cent all through. Even with technological improvement when the coke rate in blast furnace would be reduced to 0·765 tonne/tonne, he pointed out a total of 140 million tonnes of coals would be necessary only by steel plants. To this another 25·0 million tonnes, required by allied industries, would have to be added. The total then would come to about 165 million tonnes/annum.

Assuming 50 per cent extraction of *in situ* reserves, by 2000 A.D., 4670 million tonnes of prime and medium coking coals would be exhausted out of a total *in situ* reserve of 11,500 million tonnes of these varieties. For hot metal production, the requirement of prime coking coal alone, in the next 30 years, would be 1100 million tonnes which is about $\frac{1}{3}$ of the 3000 million tonnes of extractable reserves.

From the above considerations Dr Lahiri theoretically showed that existing reserve of coking coal, apprehended to be exhaustible very soon, might serve the needs of iron and steel industry for another 75-80 years if due attention was paid to selective preparation, blending and technological improvement.

M/s. Sharma & Banerjee making a reference to the work done by CFRI on blending for meeting the ever-increasing need of coking coal, enumerated some of the bottlenecks for increased production and classified them as technical, economic and political. Under technical problems, they enlisted wide variations in (i) the density of coal to strata having several contiguous seams, (ii) the thickness of the same seam at different places in the same field, (iii) the gradient, smallness of the leasehold areas mostly irregular in shape, (iv) vast areas standing on pillars because of development by the board and pillar method, (v) mine fires, (vi) discontinued mines around working ones, (vii) large built-up areas and railways blocking coal reserves, (viii) problem of surface drainage in relation to mining practice, and (ix) non-availability of sand for stowing. Low productivity, high power cost and high production cost are the economic issues. Labour unrest was considered to be the only item under political problem.

Second Session

The second session discussed four papers on the conservation and distribution of coking coal with Shri B. P. Agarwalla in the Chair. The papers were: (i) Coking Coal — Some Thoughts on Its Conservation, by A. K. Mitra, Coal Board; (ii) Coal Conservation — Retrospects and Prospects, by S. K. Bose, NCDC; (iii) Distribution of Coal for Metallurgical Consumers, by D. B. Aggarwal, HSL; and (iv) Distribution of Coking Coal, by H. S. Chopra, Joint Working Committee.

A. K. Mitra reasoned that it was difficult to define a 'Coking Coal' based on the chemical properties alone because two coals having identical chemical properties may yield cokes of widely diverse properties. Pilot plant testing simulating industrial conditions followed by large scale tests, he said, are the two essential steps for correctly assessing the coking potentiality of any coal. In this context he referred to the extensive work done by CFRI alone as well as in collaboration with CBCR, Jamshedpur. Mitra viewed the coking coal problem not only in the light of sustenace of the present production rate but also in the light of increasing demand by steel plants and foundries. Such enhanced demand can only be met if the coals can be mined to the maximum extent. Conservation would result by such efficient mining. He enumerated the measures taken by Coal Board to augment the supply of sand for stowing which is expected to be in short supply in Bengal-Bihar coalfields due to erection of several dams and adoption of afforestation schemes. One such project was aerial ropeway transhipment of 5·2 million tonnes of sand from Durgapur area and the other — pneumatic stowing with surface overburden. He then apprised the gathering of Coal Board's successful implementation of the sub-level caving in method of extraction of coal in a mine in Bihar.

S. K. Bose presented an account of the problems of mining thick seam, exhaustion of coking coal due to indiscriminate mining in the past resulting in the need of washing high ash coking coals and loss of coking coal in pillars and closed mines. Assuming 50-60 per cent extraction of *in situ* reserve and 40-60 per cent yield of clean coal, he showed that the total clean coal availability for coke ovens would be $\frac{1}{4}$ or $\frac{1}{5}$ of the geological reserve. For increasing extraction from thick seams, he suggested long wall mining coupled with stowing. He also suggested combined open cast mining for a group of small working mines where the overburden would be used for surface blanketing of fire area or for stowing after proper sizing.

Bose urged that Coal Board should undertake survey on assessment of percentage recovery for various thickness groups being exploited by various methods at different mines and publish the data so that others may try for improvement in cases where the extraction will be low. Awards should also be given for such innovation, he expressed. He advised all mining companies to assign their problems to consultants or consulting bodies for possible solution. He also proposed that experienced engineers who successfully exploited efficient mining methods in one colliery, should visit and render assistance to others afflicted with inefficient mining procedure. According to him, the washery supplying clean coal to specific steel plants should be located at the same site as the steel plant for convenience and other economic reasons.

D. B. Aggarwal gave the monthly break up figures of coal for different steel plants and those of the available amount of medium coking coal from different washeries. The total availability of medium coking coal worked out to about 34 per cent of the total requirement. He proposed that steel plants should try to accommodate all the 34 per cent of medium coking coal in the coking blend in order to conserve metallurgical coal. The current practice being far from that, he urged for an equitable distribution of all varieties of coal irrespective of the ownership of the leasehold. Referring to the coal blend for Bokaro Steel Plant which is to contain 55 per cent of medium coking coal, Aggarwal pointed out that only 28 per cent of such coals would be left over for other plants. With the proposed commissioning of Gidi Washery, the share of the steel plants other than Bokaro would rise to 34 per cent. So for incorporation of larger amounts of medium coals in the coking blend for greater conservation, even if feasible, the coals must have to be first made available to the steel plants.

Demand is a vital aspect of distribution requiring continuous programming and constant adjustment observed H. S. Chopra in his paper. He also suggested that a flexible approach be adopted for fluctuations in demand in order to maintain a continuous flow in the pipe line. For coking coal, this is essential for eliminating the possibilities of discontinuous distributional operations. Referring to recurring annual shortfalls in the demand, Chopra suggested that the formation of a 'supply pool' for the period of discontinuous distribution provides a solution to this problem. As a long term measure, he opined that a judicious combination of factors such as correct demand forecasting, realistic demand programming, cost consideration and remunerative pricing should have to be adopted.

Third Session

The third session, devoted to coal beneficiation, was held with Shri C. S. N. Raju in the Chair.

Four papers: (i) A Note on the Present Pricing Policy of Coking Coal, by R. K. Dubriwala, Ranigunge Coal Association Ltd.; (ii) Beneficiation of Coal, by M. Jha, HSL; (iii) Beneficiation of Caking Coals in India, by G. G. Sarkar & A. K. Chakravorty; CFRI, and (iv) An Analysis of the Cost Coal Preparation in India, by G. G. Sarkar & R. N. Bose, CFRI, were presented and discussed in this session.

R. K. Dubriwala expressed the view that the present coal pricing policy was ideally suited to only a small fraction of the producers. As the major portion of the future demand of coking coal would have to be met by inferior quality coal from deeper seams for conservation of prime coking coal, Dubriwala said that the present pricing structure based on quality consideration alone was detrimental to the utilization of the limited reserve of good quality coking coal as well as to the development of inferior coal seams at depths. He believed that reorientation of price structure taking into consideration the cost of production

and profit was the most realistic way of overcoming many prevailing impediments confronting the collieries.

M. Jha re-emphasized the necessity of washing high ash coking coals and gave a detailed account of the central washeries set up for this purpose under HSL. Talking about economics of washing, he said that proper utilization of byproducts was the prime factor for alleviating the strain on washeries. At the time of installation of these washeries, it was envisaged that the middlings would be used in nearby thermal power stations. Due to non-flexibility in design, the power plants in most cases failed to make use of the high ash middlings. Necessity, therefore, grew for further beneficiation of the middlings. Jha suggested that the high ash rejects, produced as a result, should be utilized for stowing for improved economy. Transportation of raw coal and washed products through wagons, he said, was costly for short distance haul. Cheaper means of conveyance such as aerial ropeways, belt conveyors, etc., might further improve the economics.

While discussing the performance of different washeries, Jha touched on the problems arising out of varying quality of feed coal, interrupted power supply, non-availability of coal supply in time, non-availability of standard quality spare parts, etc.

G. G. Sarkar and A. K. Chakravorty drew attention to the multiplicity of washery components required for beneficiation of coals of varying washing characteristics. They studied the reasons for shortfall in rated capacities of different washeries and found that almost one-third of the country's available washing capacity remained unutilized mainly due to non-availability of such varied but essential spare parts. Considering the present operating conditions and the trend of supplies of raw coal to future washeries, the authors suggested a simple and compact washing circuit for coking coal and rationalization of design and washery components. According to them, standardization of design and capacity of the washeries might lead to indigenous manufacture of complete washery equipment solving thereby the problem of spares. The authors demonstrated why it would be necessary, in future, to finely crush the coals before washing and brought out the salient features of ' Oleoflotation '— a process developed at CFRI for simultaneous upgrading and dewatering of fine coal. They concluded that a collaborative approach of research and design organizations as well as manufacturing firms might help solving the problems facing coal beneficiation industry.

G. G. Sarkar and R. N. Bose ascribed the difference in cost of coal preparation to the difference in washing system or layout and to the variation in the source of supply. In their opinion the factors affecting the cost of clean coal were: (i) cost of raw coal, (ii) cost of freight and/or handling, (iii) yield of clean coal, and (iv) extent of utilization of plant capacity. The authors presented a comparative account of the cost of washing between two groups of washeries: (i) pit-head washeries and (ii) central washeries. Capital cost per tonne of throughput worked out on the average at Rs. 3·00 for central washeries and Rs. 2·50 for pit-head washeries, while the average operating cost per tonne of throughput varied from Rs. 5·00 for central washeries to Rs. 3·50 for pit-head washeries. In central washeries, cost of clean coal laid normally in the range of Rs. 60 to Rs. 70 per tonne as against Rs. 50 to Rs. 55 per tonne in pit-head washeries.

Fourth Session

In the concluding session, presided over by Shri B. H. Engineer, the utilization aspect of coking coals was discussed. The four papers presented were (i) Prime Coking Coal Resources for Jharia Coalfield and Their Bearing on Iron and Steel Industry, by N. Sen & T. N. Basu, NCDC; (ii) Utilization of Coking Coal in Iron & Steel Industry in India, by T. R. Anantharaman & G. Venugopal, HSL; (iii) Economy in Use of Coking Coal for Metallurgical Coke Manufacture, by N. G. Banerjee & A. K. Moitra, CFRI; and (iv) Groupwise Classification of the Barakar Measure Seams of the Jharia Coalfield, by B. Banerjee & M. M. Alam, CFRI.

N. Sen and T. N. Baser assessed the total net geological reserves of prime coking coal up to a depth of 1000 metres against the previous available assessment (down to a depth of 600 metres) by the sub-committee of the Committee on Assessment of Resources of the Coal Development Council (1967). The figures were calculated to be 5965 and 4140 million tonnes respectively.

Of the estimated total resources up to 1000 metres, they showed that 70 per cent occurred in the leasehold of the Private

Sector, 26 per cent in the Public Sector and the rest in the unleased areas. If a depth of 600 metres was taken into account, the distributional figures would be 82 (about half lying virgin) and 16 respectively for the first two sectors. Assuming that 50 per cent of prime coking coal would be used in the coking blends and that there would be a constant growth rate of 6 per cent per annum up to 2000 A.D. after which there would be no further growth and all the technological improvement would be implemented, the total resources of prime coking coals were expected to sustain the iron and steel industry up to 2025 A.D. Without any technological improvement, the limit might be up to 2015 A.D. They, therefore, suggested that mining engineers and technologists should strive to find out means of conservation so as to stretch the life of the meagre reserves of such a useful commodity.

T. R. Anantharaman and G. Venugopal comparing the consumption of run-of-mine coal per tonne of steel production in India and other advanced countries showed that 2·10 tonnes of coal are required in India whereas it is much less in other countries. The causes they ascribed to high ash content in coal and coke, low productivity in blast furnace due to non-incorporation of the various technological improvements and burden preparation and thirdly use of small percentage of scrap in the making of steel. Elaborating on individual aspects as mentioned above, they suggested import of low ash coals on technological grounds alone as there was less likelihood of indigenous availability of the same from washeries at economic price andi n good yield. It was stated that HSL intends to incorporate advanced technical measures such as hydrocarbon injections, high blast temperatures, high top pressure operation, humidity control of blast, oxygen enrichment, sized burden, and use of greater proportion of pellets, sinter or pre-reduced burden in their plants during Fourth Plan period. For future steel plants, Anantharaman *et al.* suggested injection of surplus coke oven gas. Alternatively the gas might be used for fertilizer production depending on the economics. HSL's tentative proposals were disclosed regarding installation of electric arc furnaces using scrap along with continuous casting units to produce billets. Towards conservation, measures like selective crushing, stamp charging, dry charging, use of formed coke, preheating of charge, addition of coke breeze and oil, etc , were proposed and the commendable work done by CFRI in these respects was appreciated. Of the problems confronted by steel plants and washeries, the wide fluctuations in the ash content and changes in sources of coal supply are the major ones. The former could be solved by proper quality control by the coal suppliers. For coal allocation, they observed that the original design of the plants, railway transportation, minimizing the overall freight charges and equitable distribution of blendable coal should be taken into consideration.

Dealing elaborately with the question of economic level of ash per cent in clean coal, Anantharaman *et al.* concluded that the overall economics could be improved by washing coal to slightly higher ash contents. Decrease in blast furnace productivity due to high ash in coke can be more than offset by improved technological measures. Middlings disposal problem would also be reduced as a result of its reduced production, they hoped.

N. G. Banerjee and A. K. Moitra dwelt on the measures of economy in use of coking coal and suggested measures like (i) incorporation of maximum proportions of non-standard coking coals in blends for production of hard coke by adopting improved techniques of coal preparation and coal carbonization; (ii) lower coke consumption per tonne of hot metal in blast furnace; and (iii) use of formed coke from non-coking coal in full or partial replacement of conventional hard coke.

Under category (i), the key improved technique of coal preparation was the selective preparation. Decrease in bulk density due to finer crushing would be taken care of by oil addition so that without affecting adversely the throughput capacity, there would be an increase in the olefines content of the coke oven gas.

Processes like stamped charging, dry and hot charging, etc., were the improved techniques in view for carbonization. Stamped charging, they showed, allowed incorporation of more of sub-standard coals in a coking blend without impairing the coke quality. The production of coke breeze was also found to go down by 3-5 per cent than that in case of top charging. As effects of dry and hot charging, Banerjee *et al.* pointed out the lower heat of carbonization, greater bulk density in the

ovens, lowercarbonization time and consequently greater throughput per unit oven volume.

Lower consumption in coke rate, they stated, can be effected by (i) increasing the iron content of the burden by preparation and pre-reduction, (ii) sizing the burden, (iii) prefluxing the charge, and (iv) using higher hot-blast temperatures and adopting auxiliary fuel injection. They highlighted the work of CFRI on all these aspects.

B. Banerjee and M. M. Alam grouped seams of Barakar Measure of Jharia coalfield into four horizons based on their geochemical characteristics, chemical analyses, washability characteristics, atomic H/C ratio and carbonization behaviour. While the coals of horizons I and II were suitable for blending after washing, the coals of horizons III and IV were mostly prime coking coals not requiring beneficiation in most cases. The authors contended that such a grouping would not only give the quality at a glance but also a perspective plan of utilization.

The symposium came to a successful end with a vote of thanks to the Chair offered by Shri S. K. Samanta, Member of the Dhanbad Symposium Committee.

— R. S. Saha, Samir Sen & S. R. R. Rao

Spotlight

ON SCIENTIFIC ACTIVITIES

Aromatic Polycarboxylic Acids by Nitric Acid Oxidation of Coal*

Oxidation of coal with various oxidizing agents had long been investigated for direct conversion of coal into aromatic polycarboxylic acids and subsequently to aromatic chemicals and other useful products. Among the oxidizing agents, oxygen under pressure in presence of an alkali, molecular oxygen and nitric acid were mostly investigated. Although experiments with nitric acid met with limited success, recently there had been a global revival of interest in this direction for reasons of economy and ease of operation. A systematic reinvestigation was taken up at Central Fuel Research Institute for studying the products and elucidation of the mechanism of the reaction.

A few samples of low rank coals, including a lignite were tested. Stage-wise oxidation by nitric acid resulted in complete degradation of coal into water-soluble acids which were immune to further degradation either by conc. nitric acid or fuming nitric acid. The other products were CO_2, NO_2, NO and a little of acetic acid. Oxalic acid formed was found to suffer further oxidation and got converted into CO_2 and water. In case of a lower rank bituminous coal, 40 per cent of carbon appeared in the form of poly-acids, 50 per cent as carbon dioxide and the rest mostly as acetic acid. Pending further investigations, higher the rank greater was found to be the proportion of carbon appearing as poly-acids.

A study of the actual ratio of NO_2 to NO indicated that most of the oxygen was perhaps contributed by nitric acid when it got converted to NO. Based on the above assumption, an empirical equation for coal-nitric acid reaction was derived and theoretical requirement of nitric acid calculated. Theoretically about 400 gm. of nitric acid per 100 gm. of coal (d.m.f.) was considered necessary. But in actual practice one and a half to twice this amount was required. The discrepancy was assumed to be due to firstly some nitric acid getting converted to NO_2 liberating less of oxygen and secondly concentration of nitric acid getting decreased with progressive oxidation.

Preliminary characterization of the gross oxidation product by equivalent weight, molecular weight, elementary composition as well as some characteristic reactions indicated that more of simpler benzene carboxylic acids like di- and tri-carboxylic acids were formed than had hitherto been recovered and identified. The acids were found to be mostly nitrosubstituted and the major component might possibly be nitrophthalic acid and/or its anhydride.

Pending complete separation, isolation and identification of the different components in the poly-acids, attempts were made to prepare phthalein derivatives such as phenolphthalein, fluorescein and eosin. The yields of such nitrophthalein derivatives were found to be significantly high varying from about 100 to 250 per cent (of the poly-acids), depending on the type of products derived. The elementary composition and behaviour of such derivatives compared favourably with those of the corresponding standard substances, prepared from standard nitrophthalic anhydride.

Although exploratory in nature, the study may open up vast possibilities of the production of many other industrial chemicals and products which are derivatives of the phthalic anhydride molecule, if the preliminary findings are proved beyond doubt.

*"Aromatic Polycarboxylic Acids by Nitric Acid Oxidation of Coal and Their Potentialities", by B. K. Mazumdar, A. Banerjee, J. M. Sanyal, S. Ganguly, A. K. Chatterjee, P. K. Sanyal & A. Lahiri, paper presented at the Symposium on Chemicals and Oil from Coal held at CFRI from 6 to 8 December 1969.

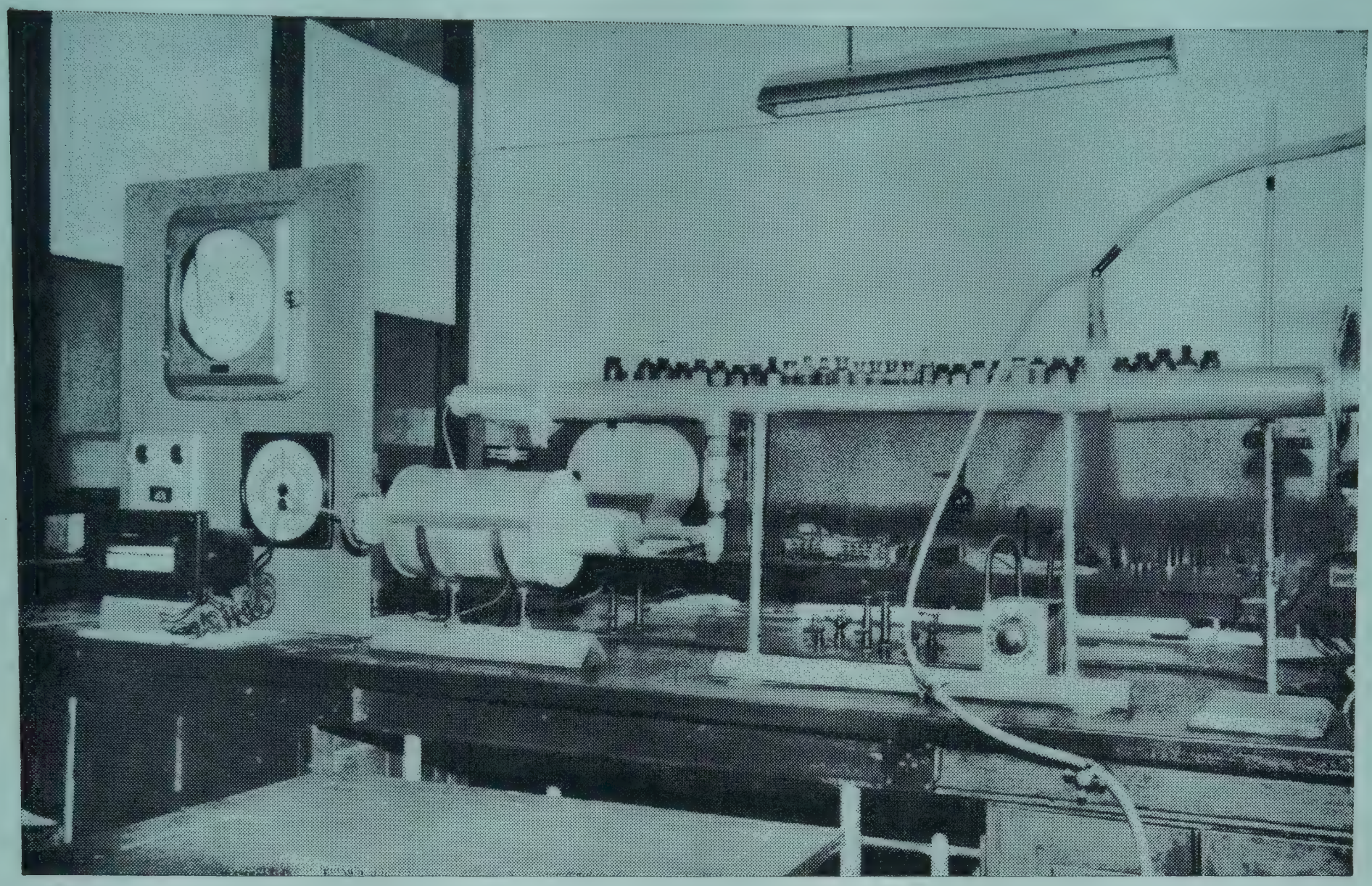


FIG. 1 — SMOKE DENSITY INDICATOR

CFRI Sets up Smoke Density Indicator

Indian Standard (IS: 4286-1967) states that there is a need for a standard procedure by which domestic fuels could be tested to give a measure of their smoke emission characteristics. Absence of any reliable method to measure smoke emission of domestic fuels presents difficulties in declaring a fuel smokeless on a scientific basis. Some work on this line have been carried out by USA and Poland.

At CFRI a method has been developed which includes setting up of an apparatus for smoke emission measurement, arriving at an acceptable minimum level of smoke in a suitable scale keeping in view of any future regulation on air pollution control and a probe into the fundamental aspects of the chemical constitution of fuels and its relation to smoke emission.

The apparatus set up recently at CFRI employs a technique of burning a few gm. of coal in a furnace and the smoke is let into a horizontal pipe through which a beam of light travels. At one end of this pipe is placed the source of light and on the other end is kept a photoelectric cell. Thus the smoke pipe serves as an absorption tube. Depending on the density of the smoke, intensity of the light beam varies and in turn falls on the light-sensitive surface of the photoelectric cell. This variation is indicated on a Galvanometer scale calibrated from zero to 100. The zero reading corresponds to full light intensity (i.e. no smoke) and 100 reading to zero light intensity. By directly reading from the scale against time it is possible to calculate smokiness of a fuel in terms of ' smoke index ' numbers. The smoke index number of anthracite is found at zero, the fuels having an index below 400 can be regarded as smokeless in a domestic oven.

Results from the burning performances of different fuels have shown that smoke index numbers decreases as the rank of the coal increases or the V.M. decreases.

Variation of Coal Properties in Relation to Depth of the Raniganj Measure Coals, Raniganj Coalfield*

Lateral variation in the coal properties of different seams of the Raniganj Measure

*Based on a paper of similar title by Anoop K. Mukherjee *et al.*

PLATE No. 1

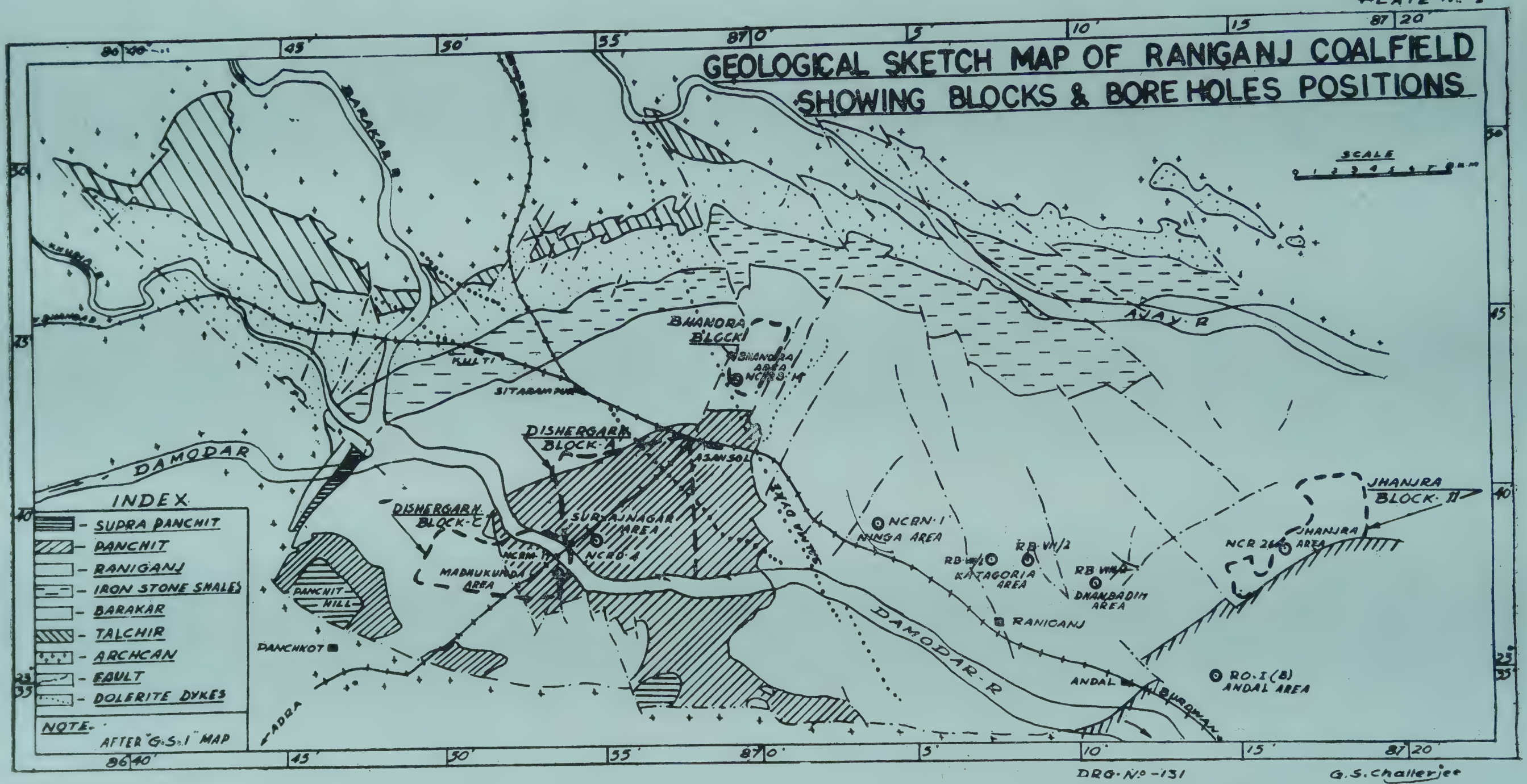


PLATE 1 — GEOLOGICAL SKETCH MAP OF RANIGANJ COALFIELD SHOWING BLOCKS AND BOREHOLES POSITIONS

(Upper Permian), Raniganj coalfield, had been studied quite extensively by the Coal Survey Laboratory of CFRI at Raniganj. Due to paucity of available information about seams at depth, the vitally important study on the variation of coal properties from seam to seam in a vertical sequence particularly in relation to depth could not be undertaken earlier. Taking advantage of the recent deep drilling projects in the Raniganj coalfield, such a study was initiated only recently.

Here an attempt was made to evaluate the rate of progressive changes brought about during the course of metamorphism by the geochemical processes, with these coals at varying depths. This was studied considering large number of analytical data of borehole coal cores drilled in various blocks/sectors of this field and the area is being divided into three typical sectors like Western, Central and Eastern on the basis of known variations of rank of coal. In accordance with the Hilt's law, a definite indication of coal maturity from seam to seam was observed in all the boreholes. The most conspicuous part of observations was the uniform rate of carbon enrichment (0·5-0·8 unit increase per 100 metres of vertical depth) and increase of calorific values (60-100 kcal./kg. per 100 metres of vertical depth). Although, there was a wide lateral variations in rank of these coals of the respective seams from west to east of this vast coalfield. It was apprehended that these high moisture high volatile low rank coals (below 85 per cent carbon level) had undergone some significant structural changes during the course of metamorphism brought about by the geochemical process of "decarboxylation and dehydroxylation". The intensity of the process enhanced with depth thereby, the rank of the coals enhanced in relation to depth. However, the process did not cause any radical change with the volatile matter and hydrogen contents, thereby, the atomic H/C ratio remained almost constant ($0{\cdot}80 \pm 0{\cdot}02$). The reduction of moisture of these high moisture coals had to an extent been accentuated by the presence of the overlying strata of considerable thickness, which had brought about certain appreciable changes in the coal-micelle, thus the moisture holding capacities were lowered with depth. The trend of variation of moisture in relation to depth attained somewhat stability around the moisture value of 2·0-2·5.

In the eastern sector, adjoining Jhanjra (rise-side) and Andal (dip-side) areas showed some contrasting coal properties. The overlying Panchet strata of 300-400 metres thickness in Andal area might have enhanced the intensity of the geochemical changes resulting in the area exhibiting contrasting coal properties like 5-6 units drop in moisture, rank maturity and development of some caking propensities in these typical non-caking coals of the eastern sector.

The study revealed the presence of potential reserve of coals of caking/blendable type in the western sector. The coals of central sector may not be similar to that of the western sector, however, the coals were caking in nature and fairly mature in rank. Another important aspect of the present investigation was an indication of the presence of comparatively low-moisture and weakly caking coals in the Andal area, underneath the Panchet strata, although the coals of the eastern sector were hitherto known as typical high moisture high volatile and non-caking type. Thus, the aforesaid area was considered to be of vital importance and required immediate attention for further exploratory work.

Fuel Efficiency Studies on Industrial Boilers

The West Coast Paper Mills, Dandeli, M.P., has long been experiencing difficulties in maintaining the required loads on their boilers with low grade coals. They have been using Raniganj coals and producing about 6·0 tonnes of steam per tonne of coal. Occasionally they were being compelled to use coals with more fines than normally expected with the consequent lowering in output of steam per tonne of coal. Because of long distance haul from Raniganj (W.B.) to M.P., the company had not only to pay extra freight but cause more strain on the already overburdened railway traffic. Moreover the assistance sought by them from various corners for exploring the possibility of replacing Raniganj coals by low grade coals of neighbouring fields met with little success.

The fuel problems of the mills were then referred to the Director of the Central Fuel Research Institute and a team of five members of the Institute was deputed in

April 1969 for conducting on the spot investigations at the mills. In course of a fortnight long investigations undertaken, eight boiler trials were performed for (i) studying the working of the boilers with the existing pattern of fuel utilization and exploring avenues for improving the thermal efficiency of the boilers; and (ii) examining the possibility of using low grade coals of neighbouring fields as such and in blends with Raniganj coal.

The tests with M.P. coals have established that these coals could be fired successfully in the boilers to meet the demands of steam of the mills without incorporating any design modifications in the furnace or adopting improved burning techniques.

It was, therefore, suggested that immediately one of the boilers be switched over to M.P. coals and subsequent to 6 months operation, both the boilers be completely switched over to M.P. coals. It was further estimated that the replacement of Raniganj coals by M.P. coals could effect a saving of Rs. 500·00 per day in fuel cost alone.

For improving the performance of the boiler and effecting fuel economy, the following measures were suggested:

(i) Running the boiler at constant and inexcessive load as far as practicable.

(ii) At any instant, the grate loading should be kept at a minimum level corresponding to the load on the boiler.

(iii) A fuel-air ratio regulator should be installed to minimize the gap in timings between the adjustments of fuel and air for any new setting of fuel rate.

(iv) As the primary air blower had a very low static head, the resistance to its passage, particularly the bed resistance, should be kept minimum. A periodical check on the actual capacity of the blower, calibration of air meters and leak-proofness of undergrate air supply should be made.

(v) The optimum moisture content of the fuel corresponding to its fines content and quality should be ascertained precisely. Aid of equipment for quick moisture determination be requisitioned.

(vi) A check on the cleanliness of heat transfer tubes and proper positioning of baffles in the gas path be made.

(vii) Some heat from the inlet feed water to economizer should be extracted by preheating combustion air and this lowering of inlet temperature of feed water would provide better scope for heat transfer in economizer. Alternatively, a part or the entire flue gas could be drawn to a separate air preheater located outside the furnace casing, as the space inside was limited for any additional installation.

(viii) Fuel should be charged to the bunker at least before it was half empty.

(ix) Fuel loss at all points outside the furnace should be minimized and care should be taken to keep the production of fines to the lowest level.

(x) Not only the leaks in furnace be repaired but also the furnace structure be made strong enough to permit operation under a little pressure, if required. The metallic casing of the furnace should be lagged.

Pyrogenic Water in Coal*

Pyrogenic water in coal, defined as the water evolved during pyrolysis of coal above 110°C., is believed to be a useful parameter for ascertaining the coking propensities of coal as well as obtaining design data for byproduct units of coke ovens with respect to yields of liquor and other condensates.

With the above objective in view, pyrogenic water content of a number of samples were determined, calculated on organic molecules basis and subsequently converted to dry mineral-free coal. This water was designated as (mp). Its correlation with various other coking parameters were then examined.

The relationship between ' mp ' and the per cent carbon (d.m.f.) showed that ' mp ' varied inversely with the carbon content. Such a relationship between hydrogen and ' mp ' was found to be almost linear after a level of 5 per cent hydrogen. A linear relationship was observed in case of oxygen content also. When the percentage of hydroxyl oxygen in ' mp ' of the total oxygen was plotted against carbon, the former was found to be inversely proportional to the latter. For a coal having 91·3 per cent carbon (d.m.f.), the per cent of hydroxyl oxygen in ' mp ' of the total oxygen was 21·7 per cent against about 60 per cent for a coal of 82·0 per cent carbon (d.m.f.).

From a graphical representation of the ratio of hydroxyl oxygen in ' mp ' to the

*[Based on a paper by D. P. Nag, T. C. Tarafdar, K. Raja & N. G. Banerjee and presented in a meeting of the Coke Oven Managers' Association (Indian Section), held at Bird's Sijua Club on 21 February 1970].

total oxygen in coal against carbon, it was observed that with increase of rank of coal, this ratio decreased and a sudden drop in the above ratio was observed after 85 per cent carbon. The relationships of atomic H/C and (O+H)/C ratio with 'mp' were also studied. The 'mp' was found to increase more rapidly with increase in atomic ratios. Caking index of coal, which is often employed to judge the coking properties of a coal was found to have no relation with 'mp'. The M_{40} and M_{10} indices of coke showed a tendency to deteriorate with a rise in the value of 'mp'. A value of 2·5 per cent for 'mp' was found to be optimum for a coking blend.

The influence of temperature of carbonization on the yield of pyrogenic water was investigated on a few coals of varying rank. For low rank coals almost the whole of pyrogenic water was evolved by 700°C, whereas in the case of high rank coals, a higher temperature was necessary.

In order to study the progress of evolution of water of hydration of Kaolinite and low temperature coal ash (prepared at 375°C), a thermogravimetric analysis on these samples was conducted. It was observed that about 95 per cent of the water in coal ash was evolved by 700°C.

The Problem of Coking Coal — *Contd from p.* 1

metal production in foundries. The cumulative demand during the next three decades for raw coking coals, allowing for losses in cleaning, will be of the order of 2471 million tonnes. This corresponds to exhaustion of total *in situ* reserves of about 5000 million tonnes of coking coal, allowing for current rate of losses in recovery in mining. This requirement in terms of rate of growth of population and the corresponding need for iron and steel, appears to be modest. Against this demand, the total estimated reserves of prime coking coals, occurring mainly in the South Bihar coalfields, are of the order of 5760 million tonnes. Dr Lahiri contends that both technologically and economically it is feasible to substitute at least 50 per cent of the requirement of prime coking coals (Group A) by medium (Group B) and semi-coking coals (Group C), the reserves of the latter estimated by him to be an additional 5760 million tonnes for Group B and nearly 7000 million tonnes for Group C coals.

It is in this context that the work of the CFRI over the past few years assumes more than an academic interest. Recently a Committee, under the chairmanship of the Secretary of the Ministry of Steel & Mines, endorsed CFRI's recommendations that the steel plants should be compelled to use at least 40-50 per cent of Groups B and C coals in blends. This alone will double the life of the reserves, for Groups A and B coals together amount to gross reserves of more than 11,500 million tonnes, against a demand of about 5000 million tonnes during the next three decades. Thus, according to the estimates of Dr Lahiri with adequate technological measures, India should be able to sustain a large iron and steel industry even by conventional techniques for several decades to come.

This optimistic prediction, however, involves several important assumptions. To start with, it is assumed that blending will be carried out at the coke ovens of the steel plants according to the above formula and this in turn involves correct layout and installation of equipment and facilities for blending and preparation of coal, especially the correct degree of crushing and selective preparation. The latter has been shown to be a must for obtaining coke of high quality from Indian coals, especially when blends of non-standard coking coals are used. So far these aspects have been woefully neglected by the steel plants. The second assumption is that there will be a progressive reduction in coke consumption in blast furnace in spite of the high level of ash in Indian cokes from the current consumption of 0·9 t/t hot metal to fall to 0·76 t/t

(*Continued on p.* 47)

Notes & News

Committees and Meetings

The meeting of the Scientific Committee of the Central Fuel Research Institute was held at the Coal Survey Laboratory, Ranchi, on 21 March 1970 with Mr A. B. Guha in the Chair.

Initiating the discussion on the progress of the Institute for the year 1969-70, the Chairman complemented the Institute for its significant success in basic and applied projects undertaken during the year. Referring to the " Project on Conversion of Assam Coal to Oil ", Mr Chander, Technical Director of TISCO, enquired about the follow-up action that would be undertaken after completion of the project. He also stressed upon the need of association and financial participation of the user industries for quick utilization of the research results. Dr Lahiri, Director, CFRI, deeply appreciated the views of Mr Chander and agreed with him on the need for joint projects. In view of varying nature of research projects from exploratory, bench scale to semi-pilot and pilot and even prototype plants, he explained that collaboration was not always possible. Having representatives from many leading fuel-based industries, both from the public and private sector, in the Institute's Executive Council, CFRI, has been keeping the industries abreast of the progress of different projects of the Institute, Dr Lahiri stated. However, he expressed that there was a limit to which any laboratory could go in making the industry to utilize research results. Dr Lahiri pointed out the interest of the Planning Commission and Govt. of India in the 'Coal to Oil' programme of the Institute. In this connection he apprised the Committee that the assistance of a top world expert in the line was made available to the Institute. The Director also mentioned the endeavour of the Institute in attracting Design Organizations as developing contractors of CFRI processes. In this respect, he informed the signing of contract with M/s, Chemical & Metallurgical Design Co., New Delhi, for design and supply of turn-key plants to exploiting industries for the processes on production of benzaldehyde, benzoic acid and 3- and 4-cyanopyridines. Another similar tripartite collaboration was in the offing between a leading American Engineering Firm, their Indian Associates (McNally Bird & Co.) and CFRI on 'Oleoflotation'. Dr Lahiri also informed the release of another CFRI process — anthraquinone from anthracene, to a design firm of Bombay. In the light of the above, the Committee and the Director welcomed the offer of Mr Chander for initiating steps for the participation of a Tata Subsidiary in exploiting the 'Selective Preparation' technique developed by the Institute. With respect to solution of problems on boiler availability, designing of improved boilers and adoption of new combustion technique, the Director stated that CFRI would welcome joint discussion and financial participation of leading boiler manufacturers like A.V.B. at Durgapur. He felt that organizations like CWPC and BHEL (Trichinapolly) should also be interested in such collaborative ventures.

In answer to an enquiry on the 'Coal to Oil' programme, Dr Lahiri spelt out the need for integration of oil production with chemical manufacture and listed the names of possible chemicals that could be prepared economically from such a project.

On being requested by the Chairman to briefly describe the major achievements of the Institute for the year, Dr Lahiri referred to the two feasibility studies by a Chemical Engineering Consulting Firm on production of Formed Coke for domestic, industrial and metallurgical use by CFRI technique. He apprised the Committee that CFRI was acting as coordinating agency in the setting up of a 300 tons/day formed coke plant by the IDCOL, Orissa. He also informed that CFRI prepared a project report containing a section on formed coke production for Audyogik Vikas Nigam, M.P., for utilization of coal from a NCDC Colliery in M.P. References were also made to the development of a silicon coke for use in ferro-alloy industry, sponsored projects on boiler availability and problems of erosion at DVC and Patratu Thermal Power Stations, utilization of fly ash, processing of heavy residues from Gujarat Refinery, utilization of IOMEX, production of electrode coke for use in aluminium industry and development of processes for pelletizing low grade coals and middlings for domestic use. Discussing the financial participation of sponsoring authorities of projects, the Director opined that even a realistic estimate of the cost involved for the work was likely to scare away the sponsoring industry and as such the CSIR policy had been to levy only a nominal charge. The Director referred to the large amount of work done by the CFRI gratis or at considerable concession for Government departments like GSI, Coal Board, Railway Board, Directorate of Mining & Geology of State Governments.

Following this, the Committee discussed the research projects for the year 1970-71. In connection with the Coal Survey Programme, the Committee was apprised that the survey work of the Jammu Survey Laboratory was nearing completion and as such the Laboratory would be wound up and a new one was to be set up at Talcher (Orissa). It was further informed that as a result of such physical and chemical survey through such survey laboratories, it was possible to locate newer sources of prime coking coal.

The Committee highly appreciated the Boiler Fuel Ecffiiency Studies conducted by the Institute for various private and public sector industries and expressed the desire for extension of such services to a larger number of organizations. To this, Dr Lahiri said that the absence of adequate number of experienced personnel was a great handicap in this regard. He assured that CFRI would spare no pains to render such assistance.

The Committee felt the need of further strengthening the basic research schemes. To this end,

inviting foreign experts and arranging for discussion with them was suggested by Dr Chatterjee. The Chairman stressed priority of discussion on steam-iron process for the production of hydrogen. Dr Chatterjee suggested similar group discussion on Fuel Cells.

The Committee approved the effort of the Institute in soliciting the assistance of the NRDC for establishing a multipurpose oxidation reactor in collaboration with industry. Offers of sites and collaboration have been received from M/s. Bararee Coke ovens and Durgapur Chemicals.

The Committee agreed to the proposal of purchasing a Graphite Element Resistance required for research investigation purposes.

Prior to this meeting, Expert Panels of the different divisions of the Institute held their meetings at the Institute to discuss the progress of work and research projects for the year 1970-71.

■ The 37th Annual General Meeting of the Indian Colliery Owners Association, Dhanbad, was held at Dhanbad on 30 March 1970 with Mr Rashiklal Worah as the President.

Stressing the need of popularizing soft coke, Mr Worah said that the 'green revolution' could considerably be helped by the coal industry by providing coal and soft coke as domestic fuels conserving thereby organic manure of cattle-dung and farm wastes for improvement of the fertility of the soil. Mr Worah observed that, although soft coke was gaining ground as the most convenient domestic fuel, the demand of coal for brick burning had been even below normal.

Coal being the primary source of power for several industries and a basic raw material for many other industries, any increase in the freight of coal haulage, Mr Worah opined, would consequently lead to the increase in production cost of the finished products and hence the goods would not be competitive.

Mr Worah voiced concern at the fast changing-over from coal to oil for loco power. He urged the railway authorities to reconsider the matter and revert to coal for loco traction.

Abolition of the grades of coking coal, in view of the controversy between producer suppliers and the consumers of coking coal over the matter of joint sampling, was disapproved by Mr Worah. He felt that a long term contract between the parties would be more conducive. In the interest of the consumers of metallurgical coal, he suggested that the collieries linked up with the Central Washeries should not be disturbed. The supplies of the medium grade coking coal, according to him, could only be maintained properly, if they were drawn for the washeries without interruptions.

He contended that the Coal Board should devote more time for increased production by encouraging stowing and helping in tackling difficult mining conditions.

On the question of amalgamation of small collieries and the proposed Bill for acquiring coal mines by the Government, Mr Worah said that this policy would not prove conducive to the growth of the industry.

Urging for closer contact between the industry and the research organizations, Mr Worah referred in appreciative terms to the work of Central Fuel Research Institute on the production of 'formed coke' and techno-economic feasibility study of production of oil from coal in an integrated coal-petroleum refinery based on coals and natural crudes of Upper Assam. He hoped that such new uses of coal might further contribute to the development of the coal industry. He also commended the Central Mining Research Station for its work on problems of interest to industry.

■ The Sixth Annual General Meeting of Soft Coke Producer's Collieries Association (SCPCA) presided over by Mr Mahinder Pratap Narang, was held at Dhanbad on the 31 December 1969.

Mr Narang observed that in future the country will have to depend largely on inferior grades of coal for her industrial growth. Hence collieries producing such coals should be extended incentive instead of stern apathy.

On the complaint of not implementing the recommendations of the Central Wage Board for the coal industry by small collieries, Mr Narang urged the Wage Board to categorize the units of the coal industry strictly on the basis of their size, investments and capacity to pay.

Besides the problems of railway transport for moving the production, the system of distribution of soft coke came up for criticism by Mr Narang.

Referring to the policy on the part of certain power plant authorities in refusing to accept lower grades of coal for their boilers although the boilers were designed to burn the same, Mr Narang urged the concerned authorities to take necessary steps so that the wasteful practice was discontinued forthwith.

Mr Narang expressed need for more intensive research on low grade coals. He referred to the important work of Central Fuel Research Institute in this line and solicited greater encouragement to the Institute and other allied institutions from the Central Government.

Commercialization of CFRI Processes

Central Fuel Research Institute on behalf of CSIR entered into an agreement with Chemical and Metallurgical Design Company (P) Ltd. (Chem. Metal), a reputed development contractor firm of New Delhi, for commercial exploitation of the processes for the production of 3- and 4-Cyanopyridines developed at the Institute. Chem. Metal will undertake design and engineering of the plants and supply turn-key plants to exploiting enterpreneurs.

CFRI processes use beta-picoline for 3-Cyanopyridine and gamma-picoline for 4-Cyanopyridine production, the raw materials for both the processes being available from coal tar, a byproduct of coal carbonization. The technique employed is the catalytic vapour phase transformation of the picolines to corresponding cyanopyridines in a single step through the reaction between the bases, ammonia and air. The processes yield pure products in good yield (more than 90 per cent) and dispenses with costly imported oxidizing agents, hitherto being used. Another distinguishing feature of the processes is that they can be operated on a continuous basis.

CFRI Process Patented Abroad

Since first filing a patent in India in 1965 on the development of a process for simultaneous upgrading and dewatering of small coals (Oleoflotation), it has been accepted for grant of patent rights also in USA, France and UK. Negotiations are also underway with McNally-Bird Engineering Company, Kumardhubi, Dhanbad (Indian subsidiary of the American firm McNally, Pittsburg), for commercial exploitation of the process.

In the CFRI process, crushed coal or natural smalls are wet screened at 1·0 or 0·5 mm. The undersized slurry is thickened to 35-40 per cent solid content in a static thickener with a rake or in a settling cone by any commercial method. The thickened slurry is

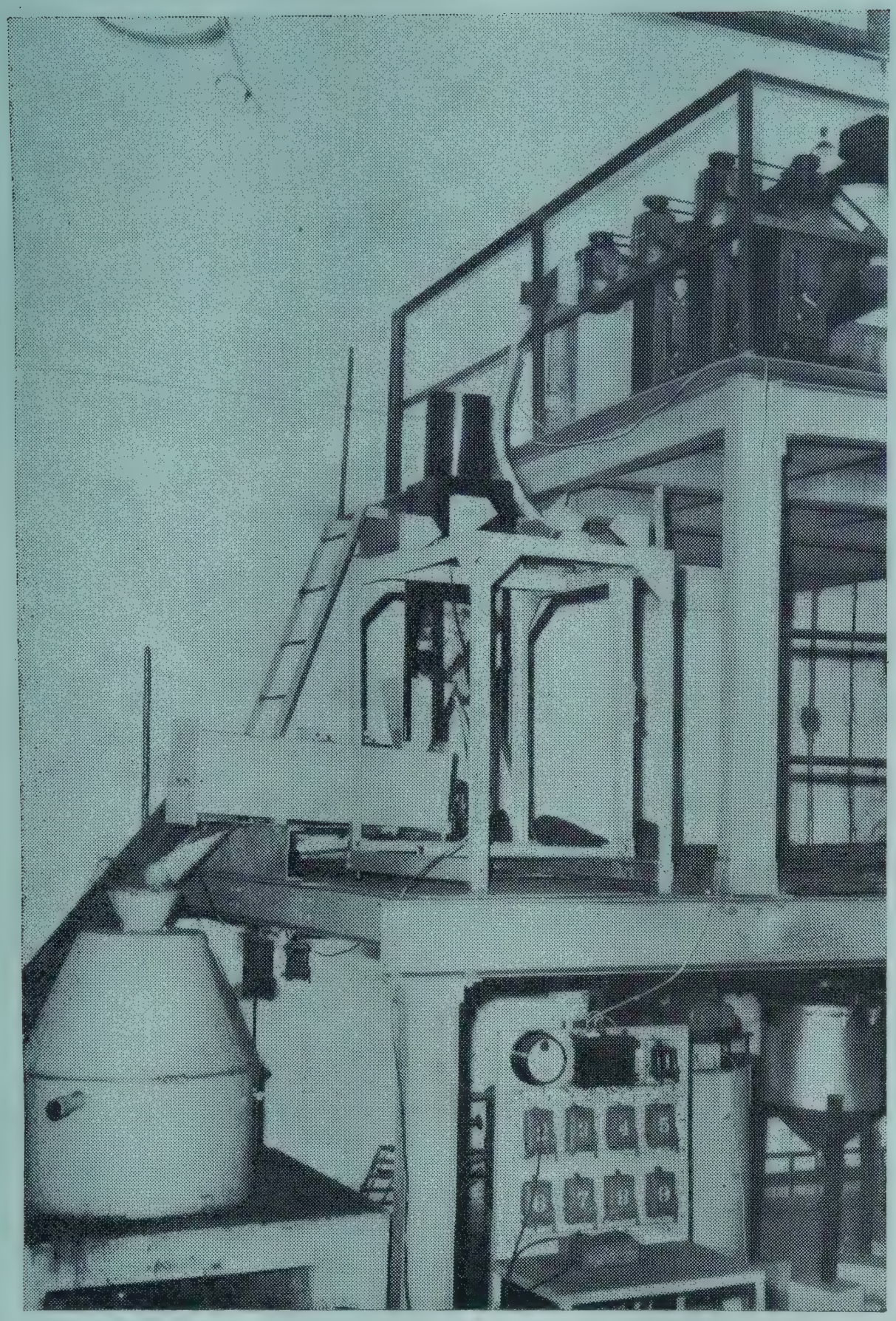


FIG. 1 — OLEOFLOTATION TESTING PLANT (CAPACITY 250 KG/HR.)

then mixed with 1-5 per cent (normally 1-2 per cent will suffice) diesel oil and 0·05-0·2 per cent LTC tar oil. The oiled pulp is diluted to a solid consistency of 20 per cent and the flocs are rafted or floated by aeration. The rafted flocs are removed and partially dewatered on a curved wedge-wire static screens. The partially dewatered product is mixed with oversize clean (+0·5 mm. clean fraction only) and dewatered in basket centrifuge. In case of minus 1 mm. slurry, the partially dewatered product is directly centrifuged for final dewatering. The advantages of the process are:

(i) Simultaneous upgrading and dewatering of fine coal.

(ii) Only one-third or one-fourth the quantity of oil required in other commercial processes is needed.

(iii) The process eliminates the use of costly equipment like special type of mill for dispersion and mixing of oil with coal slurry, vacuum filter and thermal dryer for dewatering, etc.

(iv) The major portion of the added oil is recovered with floated flocks which facilitate dewatering, handling and also improving bulk density of the coke oven charge.

(v) The process yields a product having a moisture content of desired acceptable limit.

(vi) The method of dewatering is easy.

CFRI Participation in Symposia

■ Dr I. P. Singh, Scientist, CFRI, attended a Seminar on "Catalysts and Synergists", organized by the Science and Technology Society, Kanpur, and held on 24-25 January 1970 at GSVM Medical College, Kanpur. Dr Singh presented a paper on "Catalytic Activation of Hydrogen in the Precipitation of Metal Powders and Metal Deposits" which was the first key paper discussed at the Seminar. Another CFRI paper entitled "Vanadium Catalysts in the Oxidation of Hydrocarbons" by Shri C. S. B. Nair was also presented.

■ Dr H. S. Rao, Asst. Director, CFRI, attended (i) Science Congress held at IIT, Kharagpur, from 3 to 9 January 1970, and (ii) The Convention of Spectroscopists also held at IIT, Kharagpur, on 1 January 1970.

■ CFRI scientists presented five papers to the symposium-III on "Coal Mining Industry — Its Perspective and Problems", held at CFRI from 14 to 15 February 1970 under the joint auspices of the Mining Geological and Metallurgical Institute of India and the Joint Working Committee of different mining Organizations with Co-sponsorship of Coal Board, Institute of Engineers (India), NCDC and HSL. This particular symposium discussed the Problems of Coking Coal — Its Production, Conservation, Distribution, Beneficiationand Utilization. The CFRI papers were: (i) Demand, Reserves and Planned Production of Coking Coal in India by Dr A. Lahiri; (ii) Beneficiation of Coking Coals in India by G. G. Sarkar & A. K. Chakravarti; (iii) An Analysis of the Cost of Coal Preparation in India by G. G. Sarkar & R. N. Bose; (iv) Economy in use of Coking Coal for Metallurgical Coke Manufacture by N. G. Banerjee & A. K. Moitra; and (v) Groupwise Classification of the Barakar Measure seams of the Jharia Coalfield by B. Banerjee & M. M. Alam.

[An article reviewing the sym posium appears elsewhere in this issue of the News].

■ Mr N. G. Banerjee, Scientist, CFRI, presented a paper entitled "Pyrogenic Water in Coal", by D. P. Nag, T. C. Tarafdar, K. Raja, N. G. Banerjee & A. K. Moitra at the annual meeting of Coke Oven Managers' Association held

at Birds' Sijua Club on 21 February 1970.

■ A paper entitled "Processes and Projects for the Production of Fine Chemicals Based on Coke-oven and Petroleum Stock Toluene", by R.N. Bhattacharya, Subodh K. Ray, H. S. Rao & A. Lahiri was submitted to the Seminar on Chemical Industries held at the Indian Institute of Technology, Madras on 7 and 8 March 1970.

Training at CFRI

(i) M/s. Ravi Sharma & N. Surya Rao, students of M.Sc. (Ore dressing) Course from Andhra University (College of Engineering), Waltair, undertook a short term training from 23 December 1969 to 5 January 1970 in coal preparation at CFRI.

(ii) M/s. R. K. Banerjee, B. P. Sinha & G. S. Verma, Senior Technical Inspectors of NCDC, undertook a week long course in sub-sampling, analysis & testing and determination of caking, swelling and grindability indices of coal at CFRI.

Foundation Stone Laid for World's Biggest Coal-Based Fertilizer Plant at Talcher

The foundation stone of the first of India's three proposed coal-based fertilizer plants and the world's biggest of that kind, was laid at Talcher, Orissa, on 3rd February 1970 by Dr Triguna Sen, the Hon'ble Cabinet Minister for Petroleum and Chemicals. Of the other two plants, one is scheduled to be set up at Ramagundem, Andhra Pradesh, and the other at Korba, Madhya Pradesh. The plant at Talcher is expected to go on stream in 1973-74.

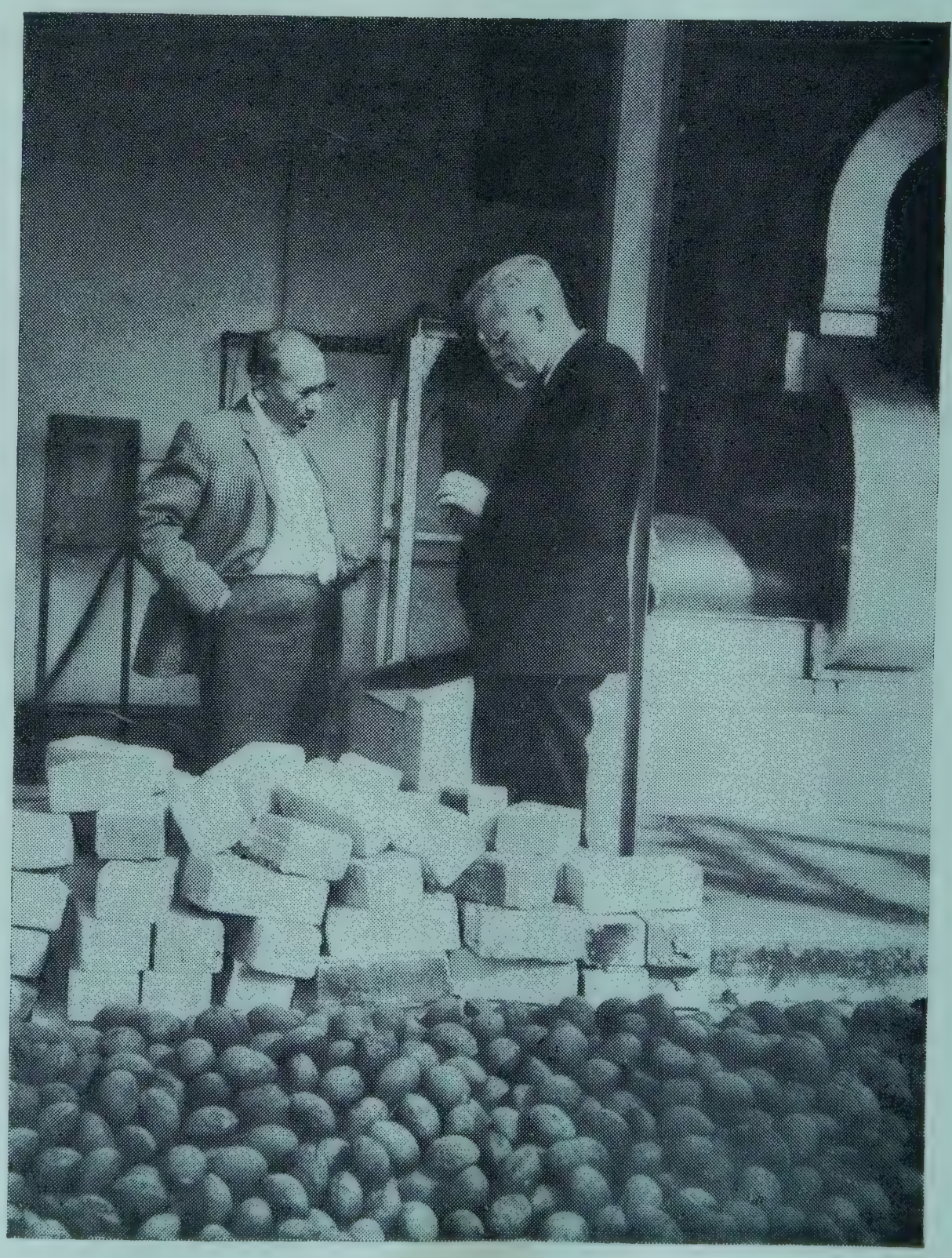
The Talcher Fertilizer Plant is based on the Feasibility Report by Fertilizer Corporation of India. The know-how, design, and engineering will be all indigenous. The project is estimated to cost more than Rs. 70 crores of which Rs. 20 crores will be in the form of foreign exchange for import of equipment not manufactured in the country.

The plant is designed to produce annually half a million tons of urea and a quarter million tons of ammonia. The supply of coal, about a million tons per year, is to be obtained from South Balanda mines of Orissa. Water requirement, estimated at 15 gallons per day, is proposed to be met by pumping water either from the Brahmani River or the proposed Tikra Irrigation Project. The State Electricity Board will supply the power requirement, 35 MW per hour, from Talcher Power Station. The cost of production for urea by the plant has been anticipated at Rs. 340·00 per ton against Rs. 370·00 from naphtha based plants. The projection of investment and production costs of the plant indicate that there will be a return of about 16 per cent of the capital employed and the investment will be paid back in about four years. The project when implemented and commissioned will effect an annual foreign exchange saving of over Rs. 36·00 crores by reduction of import of fertilizers. In addition, the increased food production is expected to replace imported food grains valued at over Rs. 120 crores per annum. The project will employ about 1200-1300 workers.

The process visualized is Koppers Totzek Gasification of coal for synthesis gas ($CO+H_2$) manufacture, production of hydrogen from the gas by catalytic shift reaction, production of ammonia from this hydrogen and nitrogen obtained from liquefaction of air and manufacture of urea from the ammonia and the carbon-dioxide obtainable from the shift conversion unit. The purification of gases in various stages will be performed by the application of the well-known 'Rectisol' Process.

Visitors

The following were some of the notable among a total of 275



Dr A. Lahiri, Director, CFRI (*left*), is explaining the process of Formed Coke production to Dr Donald L. Fuller, Science Attache, U.S. Embassy, New Delhi

MEMBERS OF THE EASTERN RAILWAYS USERS' CONSULTATIVE COMMITTEE HEADED BY DR NALINAKSHYA SANYAL (*4th from left, front row*), ARE BEING EXPLAINED BY DR N. G. BASAK, DY. DIRECTOR, CFRI (*2nd from right*), DURING THEIR VISIT TO THE INSTITUTE

DR A. LAHIRI, DIRECTOR, CFRI (*extreme right*) IS SEEN DISCUSSING WITH THE SCIENCE WRITERS (*l.-r.*): MR SAMARJIT KAR, MR ROBIN BANERJEE AND MR ROMEN MAJUMDAR

visitors who came to the CFRI during this quarter:

1. Drs A. G. Weiss and W. Frank and other members of the K.F.W., West Germany [German delegation for coal-based fertilizer].
2. Dr Donald L. Fuller, Science Attache, U.S. Embassy, New Delhi.
3. 15-member team of Railway Consultative Committee including some Members of Parliament and State Legislature.
4. Three reputed Science writers, namely M/s. S. Kar, R. Banerjee and R. Majumdar along with Mr A. K. Ganguli, Editor, United States Information Service.

Appointment

We welcome Shri Subrata Kumar De who joined CFRI as Scientist 'B' on 23 February 1970.

Resignation/Transfer

We wish all success to the following of our colleagues who have left CFRI for new avenues of work:

(i) Dr N. B. Paul, Scientist, relieved on 15-1-1970 to rejoin his parent organization, ICAR.

(ii) Shri D. K. Sen Sharma, Scientist, resignation effective from 23-2-1970 (A.N.) for further studies in U.S.A.

(iii) Shri P. Bhattacharjee, JSA, resignation effective from 2-3-1970.

(iv) Shri D. K. Pal, JSA, resignation accepted on and from 31-3-1970.

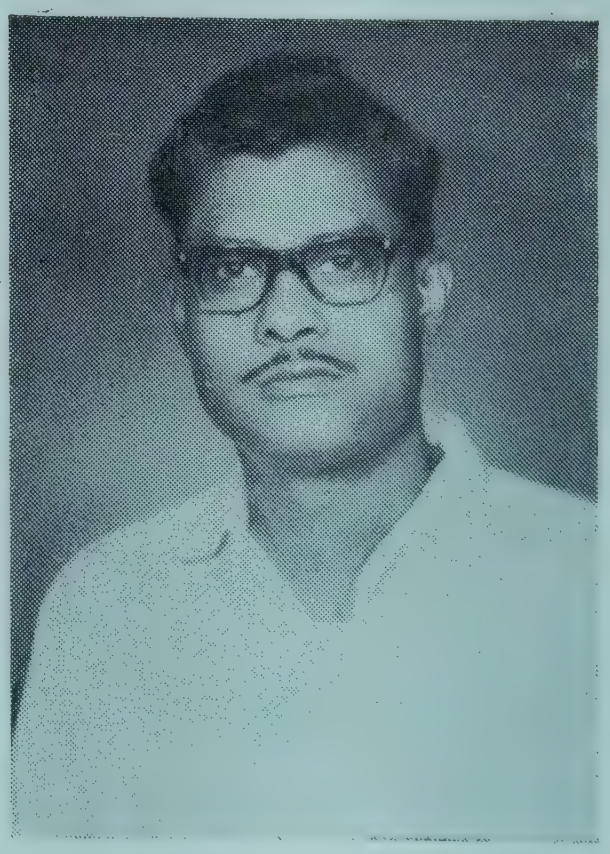
(v) Shri M. C. Das, JSA, transferred to RRL, Jorhat, w.e.f. 8-1-1970 on promotion to the rank of SSA.

Deputation

(i) Dr P. N. Mukherjee, Scientist, was deputed to U.K. on 23-2-1970 under an exchange programme between the CSIR and the British Council for a period of three months to study modern trends in research on Solid Catalysts.

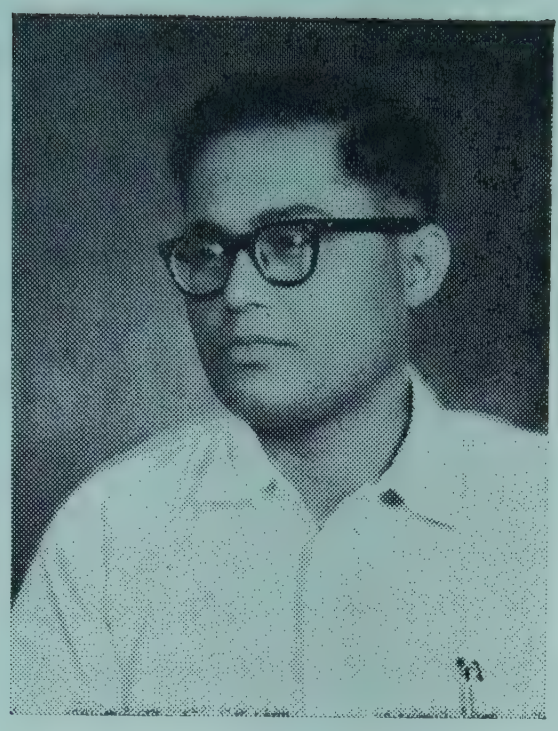
(ii) Shri S. Ghosh, Scientist was deputed to West Germany on 17-2-1970 under German Academic Exchange Programme for three months for studies in the field of Coal Petrology and Coal Geology.

(iii) Shri N. N. Chatterjee, Scientist, has resumed his duties on 9-1-1970 after completion of his deputation for three months to



SHRI S. GHOSE

Shri N. N. Chatterjee



Dr P. N. Mukherjee

Poland, under Indo-Polish Exchange of Scientist Programme. Shri Chatterjee studied the process developments and production of formed coke from non-coking coals in that country visiting various Institutes and laboratories under the Polish Academy of Sciences and research and development centres of the industries.

Honours, Elections and Awards

Shri G. G. Sarkar, Assistant Director, has been nominated as Member Secretary of a Committee constituted by the Ministry of Petroleum & Chemicals and Mines & Metals, Department of Mines & Metals, Government of India, to review the performances of coal washeries.

■ Dr P. Samuel, Scientist, was awarded a Ph.D. degree by the University of Madras for his thesis on 'Chemisorption and Catalytic Transformations on Desulphurization Catalysts — Kinetics of Hydrogen Chemisorption by Elovich Equation.

Editorial Change

Consequent to the assignment of a new project to Shri Paresh Nath Ash, Assistant Editor, *FRI News*, Shri R. S. Saha, SSA, takes over charge of the above responsibility from this issue.

OBITUARY

The members of the staff of CFRI regret to learn of the sad demise of Dr N. R. Kuloor, who was the Professor of Chemical Engineering in the Institute of Sciences, Bangalore. Besides being an educationist and a scientist, he was an expert in designing chemical plants. During his association with Shri Ram Institute of Industrial Research, New Delhi, Dr Kuloor designed the Phthalic Anhydride Pilot Plant at CFRI.

CFRI ABSTRACTS*

TECHNO-ECONOMIC FEASIBILITY OF PRODUCTION OF OIL FROM UPPER ASSAM COALS, A. Lahiri & D. K. Mukherjee.

The coals of North Assam are especially suitable for hydrogenation due to their peculiar nature being unique amongst Indian coals. The *in situ* reserves of resources of such coals of Assam are estimated at over 4000 million tons. On the basis of 50 per cent recovery, they represent a potential source of 1000 million tons of oil and chemical products. The occurrence of oil and gas near the coalfields of North Assam and the quality of petroleum suggest integrated exploitation of all these raw materials. Under the present-day conditions and for the first coal-to-oil venture, such integration has major economic advantage for both. An outline of the techno-economic aspects of such an integrated project based on a conceptual process design and flow-sheet for production of both oils and chemicals are given.

The capacity of the project has been fixed at 60,000 BPD (2·5 million tons/year) of oils, of which about 50 per cent will be derived from coal. The conversion yields are based on the coals of the Makum coalfield (Upper Assam). The flow-sheet is designed to utilize only 15 per cent hydrogen from outside sources, in this case from natural gas, and the rest will be met from process off-gases.

The preliminary studies indicate that the selling price of middle distillates can be competitive with the current ex-refinery value of similar products and well below their import values, provided a certain amount of chemicals, especially aromatics and phenolics, are produced.

The byproducts and chemicals which will be produced are sulphur (42,000 t/y), ammonium sulphate (95,000 t/y), BTX (223,000 t/y), naphtha for chemical or fertilizer feed stock (564,000 t/y), ashless coke (150,000 t/y), butadiene (20,000 t/y) and limited quantities of tar acids (61,000 t/y). Though the chemicals constitute about 30 per cent of the total weight of the oil products, their sale value is about 60 per cent of the revenue earned, thus subsidizing production costs of the energy fuels.

HYDROGENATION OF COAL WITH IRON CATALYSTS, D. K. Mukherjee, J. K. Sama, P. B. Chowdhury & A. Lahiri.

Development of iron catalysts suitable for hydrogenation of coal under 200-300 atm. operating pressure is a subject of considerable commercial interest. In the conventional practice, iron catalysts have been used under 700 atm. either as powdered oxide, as for example, in the form of red mud or as sulphate impregnated on coal or a combination of the two. Addition of extra sulphur in elemental form or as hydrogen sulphide is known to have beneficial effect on the catalytic function of iron especially for coals low in sulphur. In the present work it is observed that iron oxide, if applied in a modified form by precipitating the hydrated oxide on the pulverized coal, has superior catalytic properties particularly comparatively lower metal concentrations to the powdered oxide, both being promoted with sulphur. Iron oxide in the modified form of application is also found to have better catalytic effect than the impregnated sulphate catalyst at identical metal concentration and S/Fe ratio. Experimental results indicate that the modified iron catalyst is comparable to molybdenum even at 100 kg. per sq. cm. cold pressure and 400°C. at the respective metal concentrations of 1·86 and 0·5 g. per 100 g. of coal. It is also observed that the catalytic activities of iron and tin compares well in the metal concentrations of 1·86 and 0·5 g. per 100 g. of coal respectively provided the former is used under a slightly more drastic reaction conditions. X-ray diffraction studies on the spent catalysts indicate that iron oxide in combination with sulphur attains maximum catalytic activity within a range of ferrous sulphide composition having a general formula FeS_{1+x} where the value of x lies approximately between 0·04 and 0·1.

ON THE KINETICS OF COAL HYDROGENATION, D. K. Mukherjee, P. Samuel & A. Lahiri.

Two sets of published data on the kinetics of coal hydrogenation have been re-examined. Assuming the presence of a certain amount of refractory material in the sample, the workers referred to in the paper have shown that the reaction has all through a first order behaviour with respect to the organic benzene insolubles. The present analysis, however, is based on experimental values of organic benzene insolubles without taking any correction for the refractory material although the correction for the heating up and cooling periods as suggested by the workers in the field has been taken into consideration.

According to the present analysis, the process seems to deviate from the proposed first order consecutive reactions, viz. coal→asphaltene→oil, and indicate that the order varies with respect to the pressure and temperature of the experiment and the concentration of the reactants.

The treatment based on differential, integral and incremental methods indicates a sequential change from lower to a higher order as the reaction proceeds. At lower temperature the order varies from zero to about one with increase in the initial cold pressure of hydrogen. The overall process seems to proceed through three distinct kinetic stages depending on the temperature of reaction, of which the first stage is of fractional or near first order and the rest are of second order having different rate constants. Activation energy has been calculated for a selected portion of these three stages which is common to all the temperatures on the basis of a second order relationship.

The influence of all these parameters on the kinetics has been discussed.

EFFECT OF REACTION VARIABLES ON HYDROGENATION OF BARA-

*Papers presented at the Symposium on Chemicals and Oil from Coal, held at CFRI, from 6 to 8 December 1969.

GOLAI (ASSAM) COAL, D. K. Mukherjee, J. K. Sama, S. K. Mukherjee, P. B. Chowdhury & A. Lahiri.

Influences of various operating variables, namely pressure, temperature and time, on batch hydrogenation of Baragolai (Assam), 20 ft. seam coal have been reported. Effect of shaking as well as action of some selected vehicle oils on the reaction have been studied. Observations on distribution of carbon and sulphur in various product fractions and consumption of hydrogen under different operating conditions have been presented.

CATALYTIC HYDROGENATION OF L.T. TAR FRACTIONS, B. B. Brahmachari, M. R. Saha, P. B. Chowdhury & A. K. Ganguli.

Low-temperature tar, on distillation, yields about 35 per cent of distillate oils (free from tar acids) boiling between 200° and 350°C. and containing appreciable proportions of aromatics and unsaturated compounds. Investigations on catalytic hydrogenation were undertaken for improving the distribution of hydrocarbon types in the hydrogenated products. In a continuous flow vapour-phase reactors were studied the effects of hydrogenation of this oil at temperatures 375-400°C., pressure 1500 lb./sq. in. and space velocity 0·5-1·0 on a suitable catalyst. Aromatic and olefinic carbon contents were reduced considerably and correspondingly the paraffinic carbon increased. The naphthenic carbon increased to a little extent. The possible course of reactions leading to such change in the chemical nature of the product has been discussed. As a result of these changes in the chemical nature of the oil, the suitability of selected fractions for use as high speed diesel oils has been indicated.

STUDY OF F.T. PROCESS USING NITRIDED IRON CATALYST, Samiran Basu & V. A. Krishna Murthy.

Oxygenated chemicals consisting mainly of alcohols have been synthesized by the hydrogenation of carbon monoxide using nitrided iron catalyst in a fluid bed reactor. The catalyst was found to be highly active with a gas conversion rate of 1375 volumes per volume of catalyst per hour at 320°C. and 150 psi. The liquid products contained up to 60 per cent of oxygenated chemicals and the yields of these decreased with increase in temperature and also with decrease in space velocity. The utilization ratio was always found to be lower than the corresponding ratio in feed gas.

SURVEY OF INDUSTRIAL COKE OVEN BENZOLES: THEIR COMPOSITION AND UTILIZATION, Subodh K. Ray, G. S. Murty & H. S. Rao.

The composition of the important byproducts, benzole and benzole forerunnings from the major industrial high temperature carbonization unit in the country and the low temperature carbonization unit of CFRI (Pilot Plant) has been studied. Processes developed at the Central Fuel Research Institute based on the utilization of toluene and xylene occurring in coke oven benzole for the production of organic intermediates are enumerated and their importance in the fine chemicals, pharmaceuticals and dye-stuffs industries discussed.

UTILIZATION OF TAR OILS FROM L.T. TAR AS WASH OILS FOR BENZOLE RECOVERY, M. B. Roy, P. K. Banerjee & C. S. B. Nair.

Three fractions, viz. 230-270°, 270-300° and 230-300°C., of two low-temperature tar oil samples, obtained by carbonization of Talcher and South Balanda coals, were compared with standard wash oils obtained from a commercial source (HT tar) fractionated into the same range. The performance of the LT oils was found to be very similar to that of the standard wash oil. The behaviour of the higher boiling fraction (300-330°C) of South Balanda tar oil followed the same pattern but showed a slight decrease in benzene adsorption capacity.

South Balanda tar oils were separated into aromatics and aliphatics and the benzene adsorption characteristics of the former were found to be comparatively higher. The adsorption pattern, however, is similar to that of saturated wash oil.

HYDRODEALKYLATION OF MOTOR BENZOLE, S. K. Mukherjee, P. K. Banerjee & C. S. B. Nair

The results of investigations on the conversion of motor benzole, a byproduct obtained during the rectification of benzole, to benzene by hydrodealkylation at atmospheric pressure, have been presented. The best conversions were obtained in the temperature range 780-830°C., at a contact time of 3-6 sec. and a hydrogen/feed mole ratio around 3·0. The highest conversion of feed obtained was 82·3 mole per cent with a selectivity to benzene of 77·4 per cent. The coke formation under the optimum conditions was about 5 per cent w./w. on the feed and this increased at lower hydrogen to feed ratios. Lower hydrogen ratios also resulted in the increased production of hydrocarbons boiling above xylenes, which was about 6 per cent under the optimum conditions.

OCCURRENCE AND RECOVERY OF ALKYLNAPHTHALENES FROM COKE OVEN BYPRODUCTS, R. N. Bhattacharya, Subodh K. Ray, S. P. Srivastava, G. S. Murty & H. S. Rao.

Tar oils from high temperature carbonization, low/medium temperature carbonization (CFRI Pilot Plant), Neyveli Projects, and Drained Naphthalene Oils (DNO) from Shalimar and two major coke-ovens at, viz. Rourkela and Durgapur, have been analysed for their alpha- and beta-methylnaphthalene content by a combination of absorption spectroscopic and vapour phase chromatographic methods. Procedures have been described for isolation of the two isomeric methylnaphthalenes in the pure state from tar oils and drained naphthalene oils, and the potential importance of the alkylnaphthalenes for the production of fine chemicals and organic intermediates brought out.

hot metal by 1990. This expectation is not unreasonable if burden parameters were controlled by computerization and high fluxed sinters are used. The recovery in washing of coals is, however, expected to fall from an average of 60 per cent at present to about 50 per cent in future with increased production from inferior coking coal seams.

While the contribution of the iron and steel making authorities to conserve by blending will be a vital factor in prolonging the life of the reserves and of production of iron on an adequate scale for national needs, equally and perhaps even more important are the needs for conservation and planned production of coal, especially of the prime coking coals of Group A without which the Groups B and C coals will be useless. Dr Lahiri has also examined these problems in some detail and has shown the great weaknesses that exist in these sectors of planning. To start with, less than 10 per cent of the mines belong to the category which produce more than 25,000 tonnes per month, the rest being smaller units. More than 50 per cent of them produce less than 5000 tonnes per month. Against this background of extreme fragmentation of holdings and production units, especially in the Jharia coalfield he has examined the problem of rationalized production and preparation of coal as well as the problems of conservation in mining. In the Jharia coalfield, the home of prime coking coals (Group A), nearly 2200 million tonnes of best coal between IX and XII seams are owned by about 140-150 collieries. For an area outlined by the outcrops of the IX/X seams and up to 600 m. (in which most of the good coking coals of the upper seams lie), 140 operating units holding a total reserves of 4200 m. tonnes produce at present only 11·2 m. tonnes per annum. 81 of these units have less than 10 m. tonnes reserves each, 29 have between 10 and 50 m. tonnes reserves. Only nine units have more than 100 m. tonnes reserves each. Against this production and holding patterns, he has contrasted the need for centralized pithead washeries capacity with 400-500 t/hr producing coals not only of consistent ash content but consistent coking quality (volatiles, caking property, plasticity, etc.) so that blends can be accurately planned.

The change in the quality of the coking coal of the Jharia, both laterally and vertically, the need for centralized pithead washeries washing compatible seams, the measures needed for reducing losses in mining are some of the factors which compel a re-thinking of the production pattern of the prime coking coals in the Jharia coalfield. The production from the Bokaro coalfields, the other source of coking coals, is also largely being done by the public sector in a planned manner. The contention of Dr Lahiri is that the future of the Indian iron and steel industry will largely rest upon the ability of the country to plan production and enforce conservation (without undue increase in price) of the coals of the Jharia coalfield owned at present by the private sector. The paper in fact constitutes an introduction to a major report which he has prepared at the request of the Minister of Mines & Metals. In our subsequent issues we hope to present the other findings of this report which, we submit, should receive attention of not only our planners and the authorities, but of the public in general. New techniques such as pre-reduction of ores, electric smelting, development of synthetic coke (formed coke), injection of auxiliary fuels in blast furnace, etc., will reduce demand of coking coal in future, but by and large, scientists and technologists agree that the bulk of iron will still be produced in blast furnaces. Hence, the need for use of metallurgical coke cannot be dispensed with. It will be a sad day for the country if due to inertia or political reasons, essential steps are not taken forthwith to plan, conserve, rationalize production, prepare and scientifically utilize the coking coals which the country possesses, and in forfeit, the nation is compelled to import coking coals to sustain production in the most vital sector of our national economy.

FORM IV

(See Rule 8)

1.	Place of Publication	Central Fuel Research Institute
2.	Periodicity of its Publication	Quarterly
3.	Printer's Name	Rev. A. Delbeke, S.J.
	Nationality	Belgian
	Address	Catholic Press, Ranchi
4.	Publisher's Name	Dr A. Lahiri, Director
	Nationality	Indian
	Address	Central Fuel Research Institute P.O. FRI, Dist. Dhanbad, Bihar
5.	Editor's Name	*Chief Editor*: S. Ranga Raja Rao *Editor*: Samir Sen *Asst. Editor*: R. S. Saha
	Nationality	Indian
	Address	Central Fuel Research Institute P.O. FRI, Dist. Dhanbad, Bihar
6.	Names and addresses of individual who own the newspaper and partners or shareholders holding more than one per cent of the total capital	Central Fuel Research Institute

I, A. LAHIRI, hereby declare that the particulars given above are true to the best of my knowledge and belief.

31 *March* 1970

A. LAHIRI
Signature of Publisher

Chief Editor: S. Ranga Raja Rao

Editor: Samir Sen *Assistant Editor*: R. S. Saha

Yearly Subscription: Rs. 4 This Copy Re. 1

Available from

CENTRAL FUEL RESEARCH INSTITUTE, P.O. F.R.I., DT. DHANBAD, BIHAR, INDIA

Phone: JHARIA 6205. Grams: RESEARCH, JEALGORA

PRINTED AT THE CATHOLIC PRESS, RANCHI

Registered with the Registrar of Newspapers for India Under No.

Vol. 20
Nos. 2 & 3

FRI

JUNE-SEPT.
1970

29
14579
LIBRARY
NISCOM

IN THIS ISSUE

EDITORIAL - - - - - - - - - - 49

FEASIBILITY OF PRODUCTION OF OIL FROM COAL IN UPPER ASSAM: PART I - 50
A. Lahiri

PROBLEMS OF MARKETING AND UTILIZATION OF NON-COKING COALS—A SYMPOSIUM - - - - - - - - 67
R. S. Saha & S. R. R. Rao

PHENOXYACETIC ACIDS AND THEIR DERIVATIVES AS SELECTIVE WEED KILLERS - - - - - - - - - - - - 71
M. S. Anand
C. S. B. Nair &
A. N. Basu

SPOTLIGHT ON SCIENTIFIC ACTIVITIES

COALS OF MADHUKUNDA-PORADIHA AREA, RANIGANJ COALFIELD - - - - - - - - - - 76

FINE CHEMICALS BASED ON TOLUENE - - - - - - - - - - - 78

CFRI RECOMMENDS REMEDY FOR BOILER DEPOSITS - - - 80

NOTES & NEWS

INDIAN SCIENTISTS' DELEGATION VISITS USSR - - - - - - 81

THIRTEENTH EXECUTIVE COUNCIL MEETING - - - - - - - - 81

COAL SURVEY ADVISORY COMMITTEE MEETING, RANIGANJ 82

FORTY-SIXTH ANNUAL GENERAL BODY MEETING OF INDIAN MINE MANAGERS' ASSOCIATION - - - - - - - - - - - - 82

COAL LIQUIDS YIELD CARBON BLACK FEEDSTOCK - - - - - - 83

NEW COAL COMBUSTION SYSTEM - - - - - - - - - - - 83

PREVENTING BOILER CORROSION - - - - - - - - - - - - 84

SYMPOSIUM ON MINES MECHANIZATION - - - - - - - - - 85

CFRI PARTICIPATION IN EXHIBITION - - - - - - - - - - 85

STAFF MATTERS - - - - - - 86

VISITORS - - - - - - - - - - 87

OBITUARY - - - - - - - - - - 88
(Dr M. S. Krishnan)

CFRI ABSTRACTS - - - - - - 89

Editorial

OIL or its products are indispensable for modern industrial civilization. This vital source of mobile energy cannot easily be replaced by other sources of energy, primary or secondary, such as electricity, gas or coal. Further, apart from being the major source of mobile energy, petroleum fractions also constitute the feedstock for major and vital chemical industries, including fertilizers, man-made fibres, rubber and perhaps, in future, even synthetic protein. In the span of the next thirty years, not much in a nation's life, the import requirements of oil and its products for this country may well be over 100 million tonnes per annum. At current prices, this involves an expenditure of Rs 1000 crores a year or more in foreign exchange payments alone, apart from investment in transport, storage and refining.

The recent price-hike in import costs of petroleum products is perhaps the beginning and even though India is favourably located with regard to Middle East oil, her enormous future requirements as well as the tendency of increase in price indicate that all possible attempts should be made to make the country less dependent on this vital commodity, both in peace and in war. While all efforts must be made to intensify exploration programme for natural petroleum, including off-shore drilling and to obtain foreign leases, alternatives must also be explored for substituting oil in actual use as far as possible with other sources of energy, especially coal and electricity.

But after all possibilities are explored and all attempts at substitution are made, the gap between the resources and demand is likely to widen in future, perhaps at a rate higher than what we predict today. The obvious way to ensure continuity of supply is, of course, to pay for it by imports. The import of petroleum products is already of the order of 12-15 per cent of our export earning capacity and taking into account the rising costs as well as aspirations of other countries in industrializing, the import bills for petroleum alone may constitute perhaps 20-25 per cent of our earning capacity

(*Continued on p.* 70)

FEASIBILITY OF PRODUCTION OF OIL FROM COAL IN UPPER ASSAM: PART I

CHAPTER I

Introduction

THE process of industrial civilization has led to the inevitable substitution of non-commercial energy sources such as wood and farm wastes by solid, liquid and gaseous fuels derived from fossil sources. Since World War I and development of the internal combustion engine, solid fuels have been progressively replaced by liquid and gaseous (Fig. 1). In the USA, coal supplied only 24 per cent of total energy in 1966 compared to 36·0 per cent in 1951, and the share of oil has increased from 35 to 40·0 per cent. Even in India, with progressive industrialization, similar changes are taking place, though the rate and the order may be different. The Energy Survey of India Committee estimated the requirements of fuels for India up to 1980 (Table 1)[1]. Elsewhere the CFRI has estimated the requirement of total energy up to 2000 A.D. (Table 2)[2]. Fig. 2 projects indigenous production of oil and the increasing gap that is likely to develop between demand and production. Estimates by others are also of the same order. The figures are perhaps underestimates due to a subjective desire for suppression of the natural growth of demand for oil in a developing country like India with its great population and coal resources restricted geographically to the eastern half of the country.

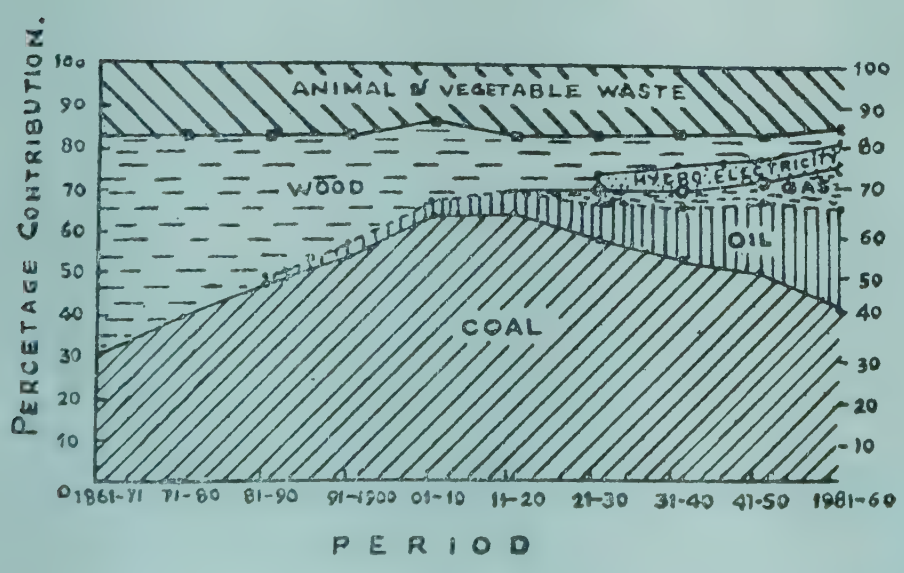


FIG. 1—CHANGING PATTERN OF ENERGY CONSUMPTION IN THE WORLD BY DECADES (1861-1950)

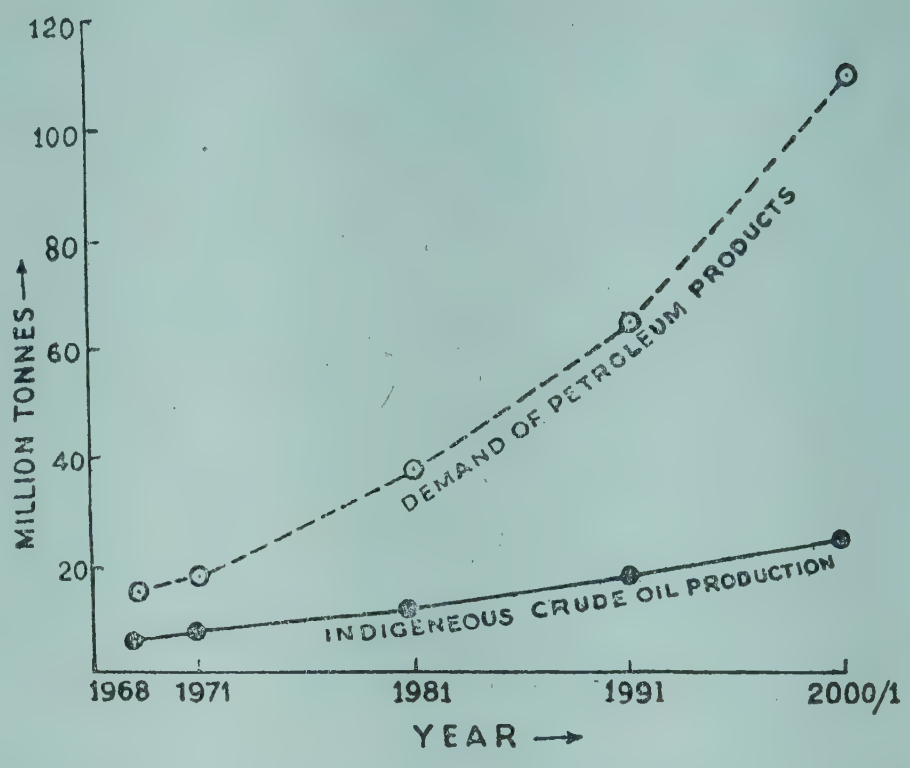


FIG. 2 — DEMAND OF PETROLEUM PRODUCTS AND AVAILABILITY OF CRUDE OIL IN INDIA

TABLE 1 — DEMAND FOR PRIMARY SOURCES OF ENERGY

YEAR	COAL (million tonnes)	OIL (million tonnes)	ELECTRICITY (billion kWh)	TOTAL (million tonnes coal equivalent)
1970-71	94·4	16·8	38·8	142·9
1975-76	145·1	27·2	59·1	221·4
1980-81	204·7	44·9	91·7	327·1

Note — On the assumption of 8½ per cent industrial and 6 per cent national income growth rate annually.

Ref.— Energy Survey of India Committee, 1965.

The gap between the indigenous production and demand of petroleum products has, of course, to be met by imports. The actual value of imports will be higher due to refining losses and import of several finished products, especially the middle distillates. The increasing annual requirements of foreign exchange for oil import is indicated in Fig. 3. The calculations are based on the assumption that only 30 per cent of the total commercial energy in India will be met by oil by the end of the century. Against this import requirement, the total foreign exchange earning capacity of the country during the last 10 years is shown in Fig. 4. The oil imports have

TABLE 2 – DEMAND OF COMMERCIAL ENERGY IN INDIA (1971-2001)

Year	Population (million)	Energy requirements by major sectors			
		Coal (million tonnes)	Oil (million tonnes)	Electricity (bill. kWh)	Total (million tonnes coal equivalent)
1971	544	93·7	19·3	47·7	151·3
1976	606	121·7	28·8	65·8	204·4
1981	676	156·0	38·1	89·5	266·9
1991	824	290·0	65·1	166·3	487·4
2001	955	589·5	110·5	324·3	949·8

Ref.— Lahiri, A. & Sinha, N. C., *VII World Power Conference*, 1968.

so far been about 10 per cent of the foreign exchange earned but may increase to 12-15 per cent in future. It is assumed that the total import bill will be of the order of Rs 17,000 to 18,000 crores in the next 30 years. Obviously, the situation is one of some concern.

It is unlikely that the imbalance in middle distillate production and demand can be remedied. Taking a longer view with a major shift of rail transport and agriculture to diesel fuels and increase in rural demand for illuminant kerosene as well as demand

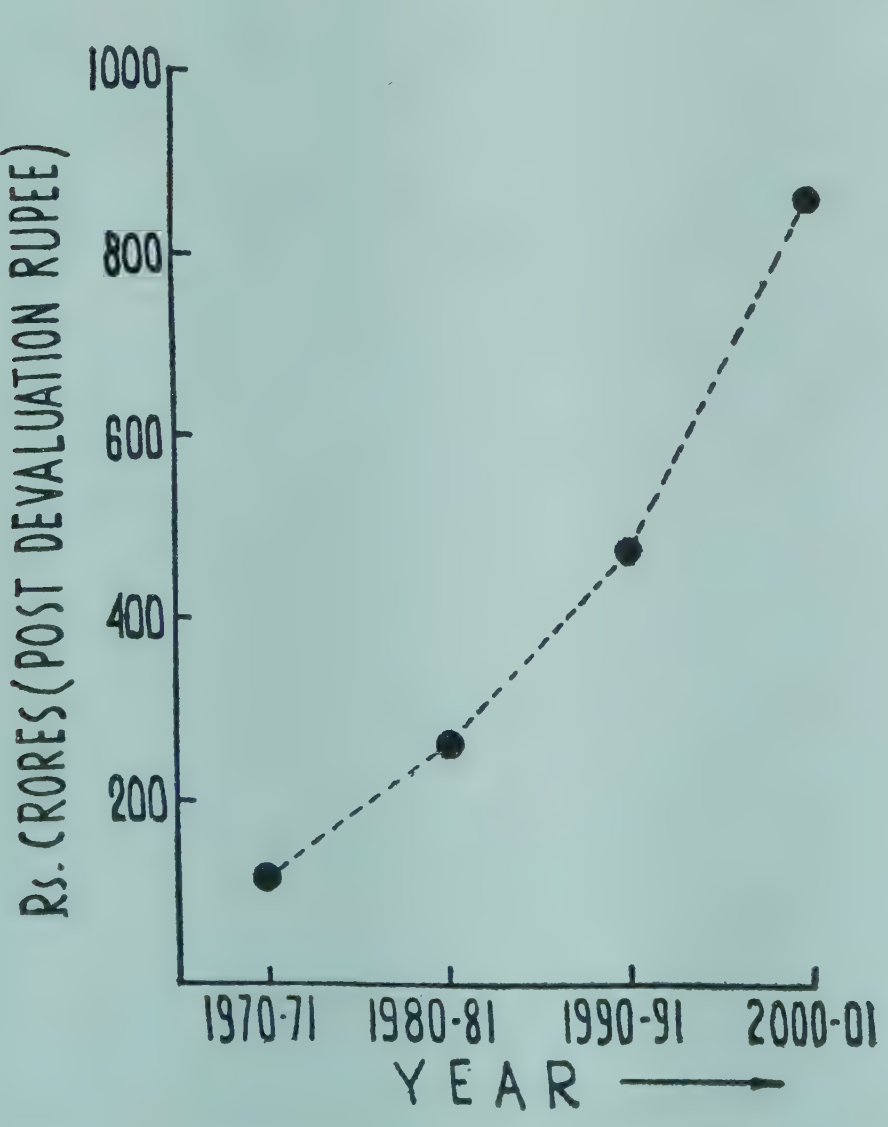


Fig. 3 — Foreign exchange requirement for import of petroleum and petroleum products (1970-71 to 2000-2001)

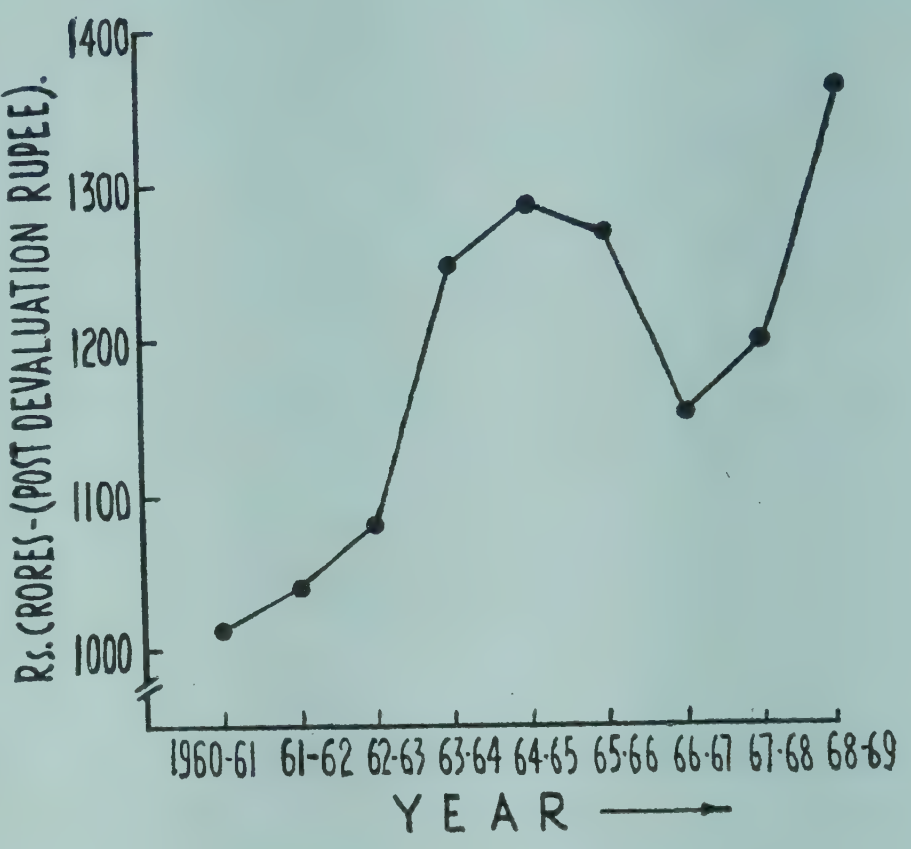


Fig. 4 — Foreign exchange earning capacity (1960-69)

for kerosene as an urban fuel, the demand for middle distillates will increase substantially and more than in the past. The increased prosperity in village that results from rural electrification almost invariably leads to demand in kerosene. Also, in the absence of supply of gaseous and smokeless solid fuels to cities and urban areas, an increase in demand for kerosene for domestic fuel purposes is inevitable. Since a feature on Indian socio-economic scene is increasing urbanization, the need for sophisticated domestic fuels will continue to grow and kerosene is by far the preferred domestic fuel for the low income groups. Again in the field of aviation fuels, transonic and supersonic aircrafts, both civil and military, will require increasing amount of special qualities of middle distillates.

Thus, the increased demand for middle distillates, disproportionate to current refinery production pattern may be inevitable. This imbalance will have to be met partially by corresponding change in the refining techniques such as by hydrogenation of heavy residues and upgrading of inferior quality middle distillates, partially through increased imports and partially through synthesis of oil from coal. These, and also the strategic requirements of fuels of special qualities, suggest that a closer look be taken at other sources for oil than import. The scope for oil concessions abroad are limited, also investments in foreign exchange and marketing problems are not easy to overcome.

Alternative sources such as tar-sands and oil shales, abundant in countries like Canada and USA, are not found in India in any commercial quantity. Coal, therefore, remains the only other alternative to resources of natural petroleum.

History of Coal Conversion

The interest in production of oil from coal was first generated in Germany and Great Britain during the World War I and the problem was intermittently investigated from various angles between the two World Wars. During the World War II, landlocked Germany, practically devoid of oil sources even with the major part of the continent under its control, ventured for the first time into large-scale synthesis of oil from coal. This was followed by Japan. After the War, commercial or semi-commercial synthesis of oil was attempted, especially in UK, USA and South Africa, and project studies were made in several countries. The only synthetic oil plant based on coal still in commercial operation is in South Africa. Perhaps such plants also exist in China, which is also poor in natural oil resources. The maximum investment in R & D effort in post-War years has, however, been in the USA, whose very basis of economy and way-of-life depend on oil and gas with an unmatched rate of growth of demand for these products.

Following a material policy review and a review of the War-time German plants, the US Bureau of Mines was charged with the responsibility of not only carrying out major basic investigations, but also of setting up a demonstration-cum-pilot plant for conversion of coal to oil for cost evaluation. Cost evaluation was done on the basis of the investigations.

More recently, the USA has become convinced that the rate of growth of demand of oil and gas in the USA will outstrip home production and fresh discoveries by 1975 and 1980 and has reacted to this challenge with its characteristic vigour and boldness. The US Department of the Interior was directed by the Congress, in 1960, to create the Office of Coal Research (OCR), to stimulate and encourage production and conversion. The OCR has adopted the strategy of contracting R & D projects to research institutes, universities and commercial firms on a national scale. In most cases, support was given to an organization which has done considerable background work and offered projects, whose feasibility was checked by consultants and experts. The projects concern not only conversion of coal to pipeline gas and oil, but also new methods of generation of hydrogen and electricity from coal. The projects, though being investigated by different agencies have often a common theme, viz. conversion of coal to oil, gas or chemicals. The current annual budget of the OCR of the order of $ 14 million (Rs 10·5 crores), with matching investment by the contractors, indicates the level of current effort. With this massive investment, a number of new techniques for conversion of coal to oil and to pipeline gas (equivalent to natural gas) have been developed and large-scale pilot projects undertaken. Reputed consulting engineers were retained to check the techno-economic data based on these processes and have forecast commercial costs. The consensus now is that petroleum products, including premium gasoline, petrochemicals and high B.t.u. gas, can be produced at competitive prices from coal in the USA. The OCR has published many of these studies. It now seems almost certain that the period 1975-80 will see the first large-scale production of oil and gas from coal at prices competitive to indigenous petroleum products or their imported equivalent in the USA.

During 1967, one of the present authors spent some time in visiting the various R & D establishments of OCR in the USA and had discussions with various authorities, as well as attended Symposia and Conferences where the prospects of the various processes under study were debated. The impression was gained that there was a

'rush' for conversion of coal to oil and gas. As one eminent technologist puts it: "The current developments provide an opportunity for investment." The 'rush' is chiefly by the major oil companies (and some chemical companies) who are confident of the new technology and possibilities and wish to secure as much coal properties as possible for future ventures. In fact, more than 25 per cent of the working coal areas are already owned by oil companies and if virgin properties are taken, then perhaps 50 per cent of mineable coal reserves of USA are under the ownership of oil companies of international standing. The search for coal concessions has extended to Canada (where working up of the tar-sands for commercial production of oil has also triggered off a similar speculation with regard to Canada's coal resources), in spite of new discoveries of oil in the Frozen World in Alaska. Coal is now considered merely as a 'dirty petroleum' and new terminology in vogue refers to 'coal refineries', 'syncrudes', 'coal oils', etc. The principal objectives are to remove the heteroatoms in coal (oxygen, nitrogen and sulphur), extract the mineral matter from coal and add a few atoms of extra hydrogen to produce a synthetic crude. The 'syncrude' is then processed by conventional petroleum processing techniques using catalytic hydrocracking, hydrofining, hydrotreating, etc.

CHAPTER II

Methods of Conversion of Coal to Oil

There are several routes to production of oil from coal. The bulk production of oil, over 5 million tonnes/year in Germany during the World War II was largely done by hydrogenation of coal and tar. High or low temperature carbonization produces varying quantities of tar oils (3-10 per cent). The yields can perhaps be increased by hydrocarbonization to as much as 20 per cent. LT tar oils has about 8 per cent hydrogen compared to about 12 per cent hydrogen in crude oil and about 14 per cent in gasoline. The problem is one of simply removing the heteroatoms by catalytic hydrogenation, which, at the same time, cracks the more complex polynuclear molecules into simpler aromatic, naphthenic and paraffinic products and thus saturating the fragments. The ratio of constituents and distribution of the molecular species and consequently the properties of the final product can be largely controlled by choice of catalysts and temperature and pressure of reaction. Normally, the yield is 90 per cent by weight and about 100 per cent by volume with low temperature neutral tar oils. High temperature tar, which is more refractory, was hydrogenated on a commercial scale by the ICI for many years at Billingham for production of aviation gasoline and other products. Tar was collected from several coke ovens. The War-time German plants were largely based on hydrogenation of tar produced from low temperature carbonization of lignites as well as on direct hydrogenation of coals. It is obvious that the scope of the route through tar oils is limited by production of tar which is a byproduct. Therefore, its availability depends on a profitable market for other products of pyrolysis, i.e. char, semi-coke or coke and gas.

If extensive programme of low temperature carbonization is undertaken in India and tar is pooled at one centre, economic units of say, 0·25-0·5 million tonne/year capacity of tar oil hydrogenation could be set up at several centres. Each plant will involve carbonization of about 2·5-5 million tonnes of coal/year. This possibility was explored and recommended in feasibility studies in 1948 by M/s Koopers Corporation (USA), who were appointed as consultant by the Government of India. This study envisaged hydrogenation of tar oils from low temperature carbonization of coals of Raniganj coalfield, integrated with a Fischer-Tropsch plant based on gasification of coke and coal fines. The 1958 study carried out by the CFRI at the instance of Government of India, excluded Fischer-Tropsch synthesis and only recommended hydrogenation of tar oils from a low temperature carbonization plant.

There is another possibility that tar oils can now be produced in high yields by fluid-bed carbonization of coal fines and the char can be used partly in large thermal power plants and/or for gasification, the gas and tar being utilized for production of oil and chemicals. A baseload 1000 MW power station, for example, will consume about 10,000 tonnes of char per day and enable production of 0·45 MMT/year of oil products, in addition to considerable surplus gas for sale or synthesis of ammonia after meeting the hydrogen

requirements. If char is produced in addition to boiler requirements, steam reformation of char can be utilized for fertilizer production. This route may be quite attractive when char fired boilers are developed. The recent innovation of fluid-bed combustion may soon reach a commercial stage which will enable even low volatile char to be used. Suitable sites for production of oil by this approach could be in the Raniganj, Singrauli, Korba, Karanpura, Singareni and the Talcher coalfields.

The second process, which was also pioneered in Germany during the War and did not contribute more than 0·5 million tonne or so of oil per annum, is the famous Fischer-Tropsch synthesis method. Coal is gasified with steam and oxygen to produce a mixture of carbon monoxide and hydrogen in the desired ratio (synthesis gas). The purified synthesis gas is reacted over catalysts. Liquid products are obtained by a complex process of hydrogenation of carbon monoxide. High costs of oxygen, power and coal (5 tonnes of coal are required per tonne of synthesis products) result in synthetic oil prices considerably higher than obtained from natural petroleum. However, by this technique, 30-40 per cent of the products can be obtained as high grade diesel fuels and jet fuels. Where coal can be produced cheaply and if petro- and carbo-chemicals and fertilizers are produced in an integrated plant, with energy fuels as subsidiaries, this approach may have a chance. This process is now being currently utilized for production of 250,000 tonnes (now being doubled) of liquid products per annum from coal by Sasol (South Africa). In India, such complexes could be conceived at one or two centres, e.g. Singrauli or Damodar Valley coalfield. The problem will be an accurate market forecast for the large quantities of organic chemicals produced and distribution of pipeline quality gas.

The third approach is one of direct hydrogenation of coal (or of solvent extracts of coal) by the Bergius process. Coal is hydrogenated first into a synthetic crude (syncrude). The coal structure is broken down and the major heteroatoms are removed and addition of hydrogen is effected to yield a product similar to asphaltic crudes. There are several established methods of treating this syncrude, by hydrocracking and hydrofining techniques, to obtain the derived end-products, gasoline, middle distillates, furnace oils and/or chemicals. It is this process in its different aspects which has received the maximum attention in the USA in current years. The US work has, however, been directed to produce exclusively premium gasoline, a product currently unwanted in India. For the present studies, therefore, production of middle distillates has been taken as the preferred end-product and processing schedules have been conceptually recast to meet the end. Of course, production of naphtha cannot be altogether avoided, but a major part of naphtha is converted into aromatic chemical products and the C_1-C_4 gases are treated as source of olefines. However, premium grade gasoline can be produced, if desired.

CHAPTER III

Basic Economics of Coal Hydrogenation

Coal Costs

One of the most important parameters affecting the cost of coal hydrogenation is, of course, the cost of coal. About 2 tons of coal (daf) are required for a ton of syncrude and if the competitive value of finished and refined products is taken at Rs 200/- a ton, then coal cost alone will constitute nearly 25 per cent of the value, with coal at Rs 25 a ton. Coal, therefore, has to be cheaply won. Most US estimates are based on coal costs at $ 3·5/tonne. Fig. 5 indicates the influence of the cost of coal on the value of middle distillates produced from the syncrude.

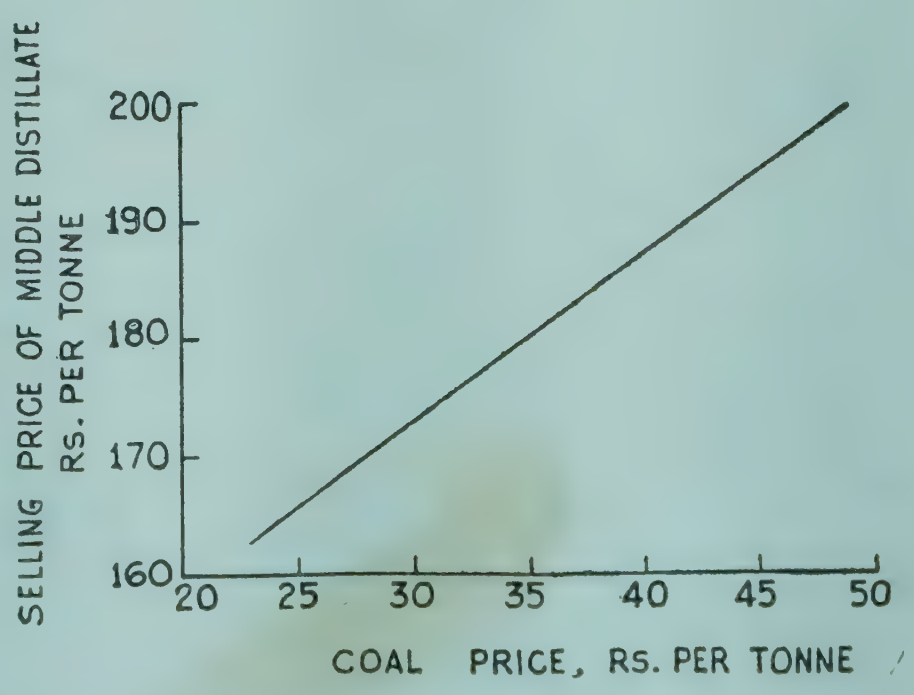


FIG. 5 — EFFECT OF COAL PRICE ON SELLING PRICE OF MIDDLE DISTILLATE

Nature of Coal

The nature of coal is also important. Obviously, high ash coals will involve greater quantities, apart from problems of removal of ash and costs thereof. Lower the ash in the coal, the better it is. The earlier German plants used 3-7 per cent ash coals and 6-13 per cent ash lignites. However, recent experiments including pilot plant trials at Hydrocarbon Research Inc., USA, indicated that 10 per cent ash coal may not be difficult to process. Perhaps even higher percentages could be tolerated, provided coal was cheap. The organic constitution of coal is also important. The higher the rank of coal, the more difficult it is to hydrogenate. Similarly, lower rank coals with too high an oxygen will have obvious disadvantages as moisture and large quantities of oxygen have to be removed. Of the petrographic fractions, the vitrinites and exinites are more amenable to hydrogenation and the inertinites are refractory.

The organic part of coals consists chiefly of aromatic and hydroaromatic carbon and small amounts of aliphatic carbon. The hydrogen in aromatic nuclei may be substituted to different degrees. The proportion of the aromatic carbon may vary from 55 to 96 per cent, hydroaromatic carbon 35 to 0 per cent and aliphatic carbon 8 to 2 per cent with increase in rank of coal from subbituminous to anthracitic. The lower rank coals contain functional oxygen groups mostly in the form of carboxyl and hydroxyl groups. The carboxyl groups predominate in immature coals and are easily removed during heating but removal of both hydroxyl and carbonyl groups (which decrease with increasing rank), involve consumption of some hydrogen. With coals above 85 per cent carbon, the functional groups and oxygen content generally decrease but the aromatic carbon in coal increases at the expense of aliphatic and alicyclic carbon, which in turn also reduces the hydrogenability of coals. Ideally, the higher the non-aromatic carbon and hydrogen and lower the oxygen content in coals, the more easily they are hydrogenated. These conditions are best satisfied in the range of 78-84 per cent carbon and in C/H range of 13-15 per cent. Higher inertinite percentage leads to increased polycondensed aromatic nuclei, irrespective of rank and lowers hydrogenability. The exinites and resinites are generally high in hydrogen and contribute both to solubility and ease of hydrogenability of coals. The existence of sulphur, which is normally a disadvantage in most other reactions and in use of coals, is an advantage here. Not only most of the catalysts have to be kept in sulphide form but in many cases sulphur has to be added to the system. The catalysts used are generally of desulphurizing type and are sulphur resistant and, therefore, sulphur present in coal or liquids is recovered in the form of sulphides of hydrogen. Sulphur evolved can be recovered almost quantitatively by established processes.

An ideal coal for hydrogenation should, therefore, have low ash, minimum aromaticity, high percentage of alicyclicity, high hydrogen, low oxygen and maximum vitrinite and exinite concentration and perhaps also high organic sulphur.

Assam Coals

Of all the coals in India, coals of Assam ideally match these requirements. Table 3 gives the average composition of Assam coals. Details are given in Appendix 1. The Tertiary coals of Assam have low ash, high vitrinite concentration and have high non-aromatic carbon concentration in the

TABLE 3 – CHARACTERISTICS OF TERTIARY COALS OF UPPER ASSAM

Characteristics	Upper limit	Lower limit
Proximate Analysis % (60% *R.H. and at* 40°*C*)		
Moisture	2·0	1·4
Ash	15·0	4·0
Volatile Matter	42·0	36·8
Fixed Carbon	49·5	45·7
Caking Index	24	5
LT Gray-King Assay		
Coke Type	G_1	B
Tar Yield (% by weight)	16	15
Ultimate Analysis % (*dmmf basis*)		
Carbon	82	80
Hydrogen	5·9	5·3
Nitrogen	1·3	1·0
Sulphur (organic)	5·0	2·0
Oxygen (difference)	8·5	7·9
Calorific Value (gross) kcal/kg (dmmf basis)	8300	7200

TABLE 4 — GRAY-KING ASSAY AT 600°C OF UPPER ASSAM AND PENINSULAR COALS OF INDIA

	Yield per tonne of dry coal				
	Coke kg	Tar lit.	Liquor lit.	Ammonia kg	Gas, cu.m. at STP
Assam					
Baragolai top	681	160	56	1·1	118·6
Baragolai 60-ft	680	159	60	0·7	110·7
Tipong 60-ft	660	179	61	0·8	110·0
Peninsular Indian					
Talcher	645	137	65	1·8	104·5
Korba	721	70	58	1·2	80·5
Argada-Sirka	707	105	62	1·1	99
Jambad-Bowla	658	110	74	1·7	109·5
Singareni	710	62·5	61·5	1·6	83·5

organic matter. It has also comparatively high hydrogen and for its rank it is low in oxygen. Normally, coals of this rank and of similar petrographic composition in India are expected to have oxygen of the order of 12-15 per cent as against about 8-10 per cent in the Upper Assam coals. The high hydrogen and low aromaticity is also reflected in high tar yields in Gray-King or Fischer Assays as will be evident from Table 4.

Apart from its ease of washability (Appendices 2 and 3) and remarkably low inherent ash content (which is sometimes as low as 1 per cent in sections of seams), the ash contains unusual concentrations of rare elements[3] (Table 5 and Appendices 4 and 5), especially germanium which is known to have catalytic activity towards hydrogenation.

The main deposits are located in north and south Assam, the Upper Assam deposits being in the Namchik and Makum area are better known. The gross reserves of Upper Assam has been estimated at 2500 million tons as against 1180 million tons in the Garo Hill area. Of these, the Makum coalfield is the best known and contains more than 1600 million tons of coal (Table 6). Existence of additional quantities of coal in areas so far not drilled in Upper Assam is also reported.

The fully proved deposits lie in the lease area held by M/s Assam Railway Trading Co. Ltd. who in their 10 sq. mile lease have nearly 270 million tons of coal (up to a depth of 300 m.). The production has varied between 0·5 and 0·79 million tons during the past 10 years and has been striving in view of the limited market for this coal in Assam due to high sulphur and friability of the coal and development of oil and gas in Upper Assam.

Assuming a 50 per cent availability of coal, the gross reserves indicate a firm availability of coal 'as mined' of the order of 1000 million tons in Upper Assam only, which in terms of syncrude is of the order of 500 million tons. This may be compared with the proved reseves of not more than 90 million tons of oil in Assam, which puts the reserves of these coals in perspective.

The current selling cost of this coal is fairly high, of the order of Rs 40 per ton. This is due to the limited market and also due to methods of mining currently used, which do not involve much of mechanization. It must be envisaged that coal will be mined cheaper by modern mechanized methods for a large-scale coal-to-oil conversion project. Even the smallest unit, 30,000 BPD of oil-from-coal will consume approximately 2·6 million tons of raw coal per annum, i.e. 500 per cent increase over the current production.

Any major plans for coal conversion in Upper Assam must, however, be preceded by detailed drilling and proving, as well as assessing the feasibility of mining and costs. The cost of mined coal assumed here is Rs 25 per ton, comparable to recent mechanized coal mines in India.

One of the purposes of making this feasibility study is to highlight the need for

TABLE 5 — ELEMENTS FOUND IN THE ASHES OF SOME ASSAM COALS

Coal samples	Ash %	Traces of elements found														
		Ag	B	Be	Co	Cr	Cu	Ga	Ge	Li	Mo	Ni	Pb	Se	V	M	Zr
Garo Hills (977-22)	1·63	++	+	++	(+)	+	+	+	++	+		+	(+)		+		+
									++			+					+
Garo Hills (977-7)	2·10	++	+	(+)	+	+	+	+	+	+		+	+		+	(+)	+
									++			+			+		+
Margherita-Namdung Colliery	2·78	++	+			++	+	+	+	+		+	+	(+)	+	(+)	+
Cherrapunji Colliery	17·94		+			(+)	++	(+)		+	+	+	(+)	(+)	++	(+)	+

++, Considerable trace; +, small trace; (+), minute trace.

Ref: Mukherjee, B. & Dutta, R., *Fuel*, **29** (1950), 190.

TABLE 6 — RESERVES OF COALFIELDS OF ASSAM

Region and coalfields	Reserves in million tons	Remarks
I. *Garo Hills*		
(a) West Darrangiri	127·00	For lower main seam by drilling
(b) East Darrangiri	31·00	
(c) Sijua	1916·00	As computed by Fox
(d) Balphagram-Pendingru	9·00	
Total	1183·00	
II. *Khasi-Jaintia Hills*		
(a) Cherrapunji	20·00	
(b) Mawlong Shella	9·00	
(c) Langrim	81·00	Needs confirmation by drilling
(d) Nongstoim	81·00	
(e) Eastern Khasi-Jawai areas	2·70	
(f) Umrileng	1·00	
Total	194·70	
III. *Mikir Hills*		
(a) Koilajan	0·70	
(b) Khumbaman Range	3·00	
Total	3·70	
IV. *Upper Assam*		
(a) Namchik-Namphuk	609·00	
(b) Makum	1663·00	
(c) Jaipur	94·00	
(d) Nazira	53·00	
(e) Rest	77·00	
Total	2496·00	

undertaking such studies and investigations as early as possible. Due to the nature of the terrain and working season in the field, drilling and proving will naturally take time for a project of the magnitude envisaged, the mining and conversion of coal should be under one ownership.

Hydrogen

Next in importance from the cost point of view is hydrogen. Table 7 shows the hydrogen contents in different fuels and

TABLE 7 – CHEMICAL COMPOSITION OF SOME COALS AND PETROLEUM

	Anthracite	Medium volatile bituminous	High volatile bituminous A	High volatile bituminous B	Lignite	Petroleum crude	Gasoline	Toluene
C	93·7	88·4	84·5	80·3	72·7	83-87	86	91·3
H	2·4	5·0	5·6	5·5	4·2	11-14	14	8·7
O	2·4	4·1	7·0	11·1	21·3	—	—	—
N	0·9	1·7	1·6	1·9	1·2	0·2	—	—
S	0·6	0·8	1·3	1·2	0·6	1·0	—	—
H/C atomic ratio	0·31	0·67	0·79	0·82	0·69	1·76	1·94	1·14

Coal analysis on moisture and ash-free basis. Ash content of coal: 3-15%.
C-fraction aromatic = 0·7. Aromatic rings per cluster, not over 3. H arom./H aliph. = 0·23.
H/C atomic ratio of petroleum residue: asphaltenes, 1·18; resin, 1·47; oil, 1·67.
Ref : Mills, Alex G., *I & EC*, **61** (1969), 6-17.

also in some typical aromatic hydrocarbons[4] About 6000-7000 cu. ft. of hydrogen is required (net) per barrel of gasoline produced or approximately 25,000 cu.ft. per ton of dry ash-free coal for conversion to liquid fuels, depending on the quality of coal treated and the refining schedule adopted.

Basically, the problem in liquefying coal is to add hydrogen and change the composition of coal from approximately C_2H, excluding oxygen, nitrogen and sulphur, to CH, which is roughly the composition of liquid hydrocarbons derived from petroleum. Hydrogen is also spent in removal of oxygen, nitrogen and sulphur in coals. The removal of heteroatoms, assuming, say 10 per cent oxygen, 2 per cent nitrogen and 3 per cent sulphur in a coal, will involve approximately 8000 cu.ft. of hydrogen per ton of coal, i.e. nearly a third of total hydrogen requirements. The major addition of hydrogen and removal of heteroatoms takes place in production of syncrude. A typical requirement of hydrogen for the coal conversion process where $\frac{2}{3}$ product is gasoline and $\frac{1}{3}$ is fuel oil according to H-coal process is given in Table 8.

TABLE 8 – REQUIREMENT OF HYDROGEN FOR COAL CONVERSION[5]

	S cf/barrel of finished products	
Coal hydrogenation	5750	
Heavy gas oil hydrogenation	565	
Distillate hydrotreating	440	
Distillate hydrocracking	480	
Naphtha hydrotreatment	63	7298
Less hydrogen produced in reformation		600
Net requirement		6700

The primary stage of coal hydrogenation thus requires nearly 80 per cent of gross hydrogen required for finished products. With hydrogen at Rs 1·50/MSCF, the cost of hydrogen could be of the order of 30-35 per cent of the value of the products. For an all-gasoline plant, a figure of $ 1·75 for hydrogen per barrel of gasoline valued at $ 5 per barrel has been estimated. Much of the hydrogen is derived from the process itself. Some processes, e.g. H-coal process, claim only 12 per cent of the total hydrogen required need be produced from independent sources, the rest being met from the off-gases of hydrogenation. Dehydrogenation for production of aromatics and other reforming operations in certain flowsheets also reduce the requirements of hydrogen. The HRI process has conceived of a closed cycle hydrogen utilization by the concept of firing reformers and other sections with solid fuel rather than with refinery gases. This may or may not be a practical solution, but others, e.g. American oil, also claim to have developed flowsheets which do not require hydrogen from external sources. Fuel gas required for heating of reformers and other sections can, of course, be produced by gasification of coal, coke or residues. In this study approximately 14 per cent hydrogen has to be supplied as net additional consumption. It is likely that in alternative flowsheets this could be reduced.

In the older German plant, the cost of hydrogen including its production, purification and compression amounted to as much as 50 per cent or more of the total cost of coal hydrogenation. Considerable savings in hydrogen costs are now possible over the German figures but since the net requirements are still of the order of 7000 cu.ft. per barrel, even for the smallest economic unit, say 30,000 barrels/day coal-to-oil plant involves production of over 200 million cu.ft. of hydrogen per day.

In the production of hydrogen required for hydrogenation, a major cost is incurred in purification and compression. Compression costs of hydrogen perhaps accounts for about 40 per cent of the total cost of the gas.

Thus, apart from cost of coal, the cost of hydrogen is crucial for any coal-to-oil process. The alternative possibilities of production of hydrogen are reviewed below. Conceptually, hydrogen could be produced by:

1. Electrolysis of water or by reforming coal with steam at high temperatures with heat obtained from an outside source, e.g. from nuclear fuels or heat supplied from a cheap power source. Both these techniques are as yet commercially unattractive, unless power could be supplied at costs well below 2·5 mills (less than 2 paise)/kWh.
2. A conventional source of hydrogen is from reforming of water gas produced from coke (as used in German plants during the War) or from gasification of coal with steam-oxygen under pressure or in a Lurgi plant.
3. Reforming or cryogenic separation of coke-oven gas which contains 50 per cent or more hydrogen, the remainder being largely methane and other hydrocarbon gases.
4. Gasification of coal with steam-oxygen at atmospheric pressure followed by shift conversion.
5. Steam reforming of naphtha.
6. Reforming of methane or natural gas.

Of the above sources, the cheapest is perhaps coke oven or pyrolysis gas which is obtained as a byproduct. This possibility is ruled out in Assam. The conventional water-gas route to hydrogen is also more costly due to the high cost of coke and cost of purification and compression of hydrogen. The modern methods of steam-oxygen gasification of coal is also costly due to high cost of oxygen and heavier capital investment required than for steam reformation of naphtha or methane (natural gas), but much depends on cost of naphtha and natural gas. Production of hydrogen from methane (natural gas) can be considered as perhaps the cheapest source and if naphtha is available at low price, then this is a second choice.

During recent years, several new processes have been conceived and are being developed for production of hydrogen from coal without use of oxygen with prospects of lowering hydrogen costs. Of these processes being developed in the USA, the following three may be considered as promising.

The Steam-Iron Process where producer gas made by gasification of coal with steam and air under pressure is used to reduce iron ore in a fluid bed which is re-oxidized with steam in another reactor, releasing very pure hydrogen under pressure. The entire requirement of power for compression of air for this process can be met from the spent gases through a gas turbine by utilizing the pressure drop and sensible heat of gases. In an integrated plant, the spent gases, albeit low B.t.u., can still be utilized for heating purposes. Fig. 6 indicates the conceptual design of such a plant developed by the Institute of Gas Technology, Chicago[6].

A second process which is now being utilized in a large pilot plant by the American Gas Association for the IGT hydrogasification process is known as Electrofluid Gasification Technique, the concept of which was developed by the Iowa State University Research Centre[7]. In this case, coal is steam gasified in a reactor where external heat is provided through electrodes. Again, no oxygen is involved and hydrogen can be produced under pressure saving compression costs.

The third process is the CO_2 Acceptor Process developed by Consolidation Coal Company[8], for which a large demonstration plant is now under erection in Rapid City in Western America based on lignite gasification. In this process, calcined dolomite is used for removal of CO_2 produced from steam gasification of coal, the heat required for gasification is provided by the heat of reaction of acceptance of CO_2. The spent dolomite is removed, regenerated and recirculated. The process in a conceptual design has been estimated to produce approximately 19 per cent char, 41 per cent

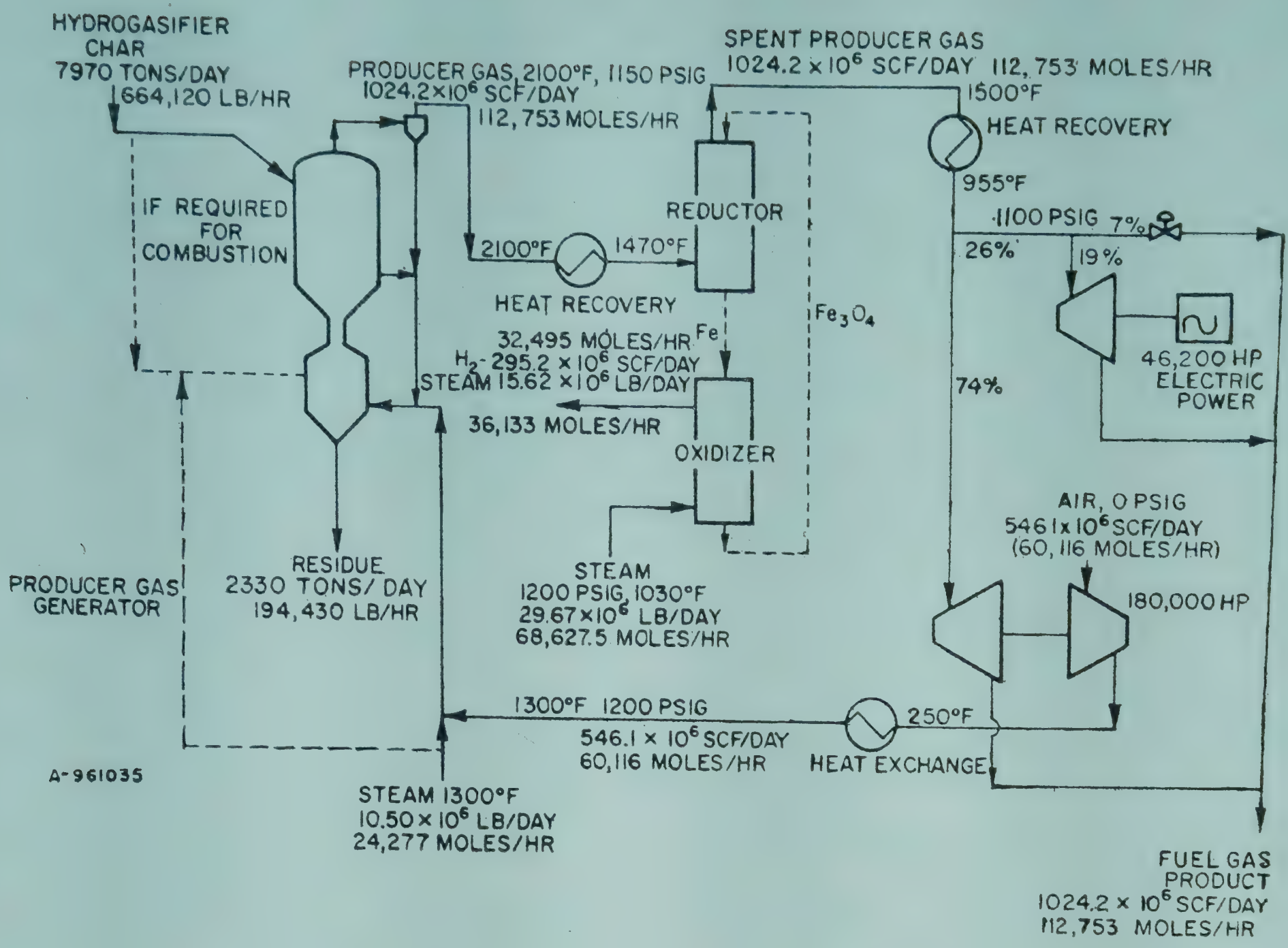


FIG. 6 — HYDROGEN GENERATION BY STEAM-IRON PROCESS

hydrogen and about 22 per cent fuel gas from a high volatile coal. With a high sulphur coal, sulphur can also be recovered as a byproduct. Integration of such a plant with a coal-to-oil complex has the advantage that fuel gas produced can meet the heat requirements of the plant and hydrogen for the hydrogenation process. It has a further advantage that a flash carbonization step integrated with the process can produce substantial quantities of low temperature tar oils which can be added to supplement syncrude produced from first stage hydrogenation. The coal is first flash carbonized at low temperatures to produce tar, char and gas. The char is then fed to the gasification system where desulphurization of the char also takes place and sulphur can also be obtained as a byproduct.

The cost of production of hydrogen by gasification of oil or by steam reformation of naphtha is now well known and is presented in Table 9, where cost of production of hydrogen by reformation with

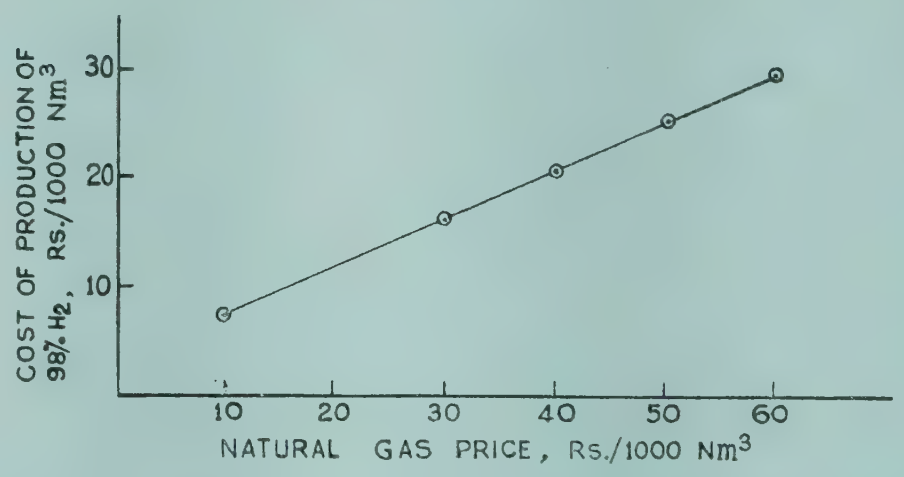


FIG. 7 — EFFECT OF NATURAL GAS PRICE ON COST OF PRODUCTION OF HYDROGEN

naphtha is compared to conventional steam-oxygen gasification of coals, such as by Lurgi Pressure Gasification technique or suspension gasification of coal at atmospheric pressure by the Koppers-Totzek process[9]. The cost of production of hydrogen from natural gas, which is likely to be available in Assam, according to the price of the raw gas, is given in Fig. 7.

For this study, the source of hydrogen has been assumed to be methane available

TABLE 9 – COST OF PRODUCTION OF HYDROGEN BY DIFFERENT PROCESSES

(Capacity : 426 million Nm^3 per year)

Cost item	Steam reforming of naphtha	Pressure gasification of coal	Gasification of dust coal	Steam-iron process (medium pressure)	Steam-iron process (high pressure)
Erected plant cost	100	176	202	275	233
Working capital	100	129	142	194	167
Raw material cost*	100†	49	39	58	43
Other direct operation costs	100	292	331	123	160
Indirect operation costs	100	173	198	269	228
Cost of production per 1000 Nm^3 of H_2	100	128	136	—	—
Cost of compression per 1000 Nm^3 of H_2 from purification exit pressure to 25 kg/cm^2	100	33	33	—	—
Cost of production of compressed H_2(96%)	100	123	130	102‡	95§

*Naphtha @ Rs 130/t. and coal @ Rs 25/t.
†Includes fuel cost.
‡99·8% pure hydrogen at 32 kg/cm^2.
§99·8% pure at 79 kg/cm^2.

at Rs 9 per 1000 Nm^3 as is currently being sold for generation of power in Assam. Any increase in price of hydrogen will naturally affect the selling costs or product pattern. Unfortunately, there is no firm estimate obtainable for availability of natural gas in Assam. Hence for a firm project, alternative sources of hydrogen must be taken into consideration unless natural gas availability is established by the time. Approximately 80 million SCF or 2·1 million Nm^3 of natural gas will be required daily. The current estimates of natural gas available at Nahorkatiya by Oil India is roughly 554,000 million SCF and the production potentiality is about 95 million SCF/day over a period of 20 years. The composition of the gas is given in Appendix 6. Part of this gas is, however, committed to fertilizer production. Reference to the Ministry of Petroleum has not revealed any new information about availability of natural gas in oil-bearing areas in Upper Assam beyond what is already known.

Mention has already been made regarding availability of hydrogen from subsequent reformation steps. In dehydrogenation of naphthenes to aromatics, considerable amount of hydrogen becomes available. Similarly, from dehydrogenation of ethane, propane, etc., additional hydrogen can be obtained. The cost of hydrogenation can be further reduced by omitting CO conversion for gases with a low carbon monoxide content. The War-time German plants had shown that CO is converted during liquid phase hydrogenation and is eliminated from the recycle gas. The savings in compression costs of hydrogen in such processes also account for considerable economy of costs of products.

Catalysts

The hydrogenation process involves operation in two or three or more stages depending on the desired product pattern. It may begin with extraction of coal by a solvent, where a hydrogen-donor solvent and/or additional hydrogen is used. This step is normally non-catalytic. The coal or the solvent extract is then slurried in a 'vehicle oil' in which finely suspended catalyst is used. The nature of the vehicle oil is important, for it is believed that it is the reactive hydrogen that chiefly contributes to liquefaction of coal. The addition of hydrogen, be it to the vehicle oil or to the depolymerized coal units, however, depends on the catalyst activity.

The finely dispersed catalyst is inevitably lost with the unreacted coal. An expensive

catalyst used in the first stage of reaction can lead to high costs unless catalyst loss can be prevented. Cobalt and molybdenum sulphides and zinc and tin chlorides, which have been successfully used, are all fairly expensive catalysts. It has been estimated (for example) that, a loss of 1 per cent molybdenum (by weight of coal) incurs an expenditure of Rs 2·70 per gallon. The German plants, therefore, chiefly used cheap iron catalysts, like iron oxides, ferrous sulphate, etc., in the first stage. These are known as 'throw-away' catalysts. Loss of 1 per cent iron catalyst will involve an expenditure of only 6 P. per gallon. Thus, catalyst life, activity and costs are important. However, cheap catalysts are not necessarily good catalysts and removal of heteroatoms may be poor and asphalt formation high in the primary hydrogenation stage.

Faced with this dilemma, two schools of approach have grown up. One believes in eliminating the unreactive matter in the first stage through solvent extraction followed by use of costly but extremely active catalysts and the second school believes in hydrogenation of coal as such in one operation with a throw-away catalyst, obtaining liquids which are then hydrocracked and hydrogenated in subsequent vapour phase treatment with highly active and selective catalysts. A variant is the process developed by HRI where cobalt-molybdenum catalyst pellets are used in suspended form in an ebulliating bed of the reactants and hydrogen mixture. It is claimed that catalyst losses have been reduced to less than 500 g per tonne of coal hydrogenated. The cost may not exceed 12 P. per gallon.

At the CFRI, so far, experiments have been conducted on the basis of two-stage catalysis, i.e. using a cheap catalyst in the hydrogenation stage and using standard and more selective catalysts for subsequent hydrocracking, reforming and hydrotreating, etc. With the CFRI catalyst, in batch operation, the same conversion yields with Assam coal was obtained with iron catalyst (at higher concentration) as compared to molybdenum catalysts. With massive doses of iron catalyst, higher conversion had been reported, but only at high hydrogenation pressures, i.e. 700 atm. With the CFRI catalyst with a much lower concentration of iron catalyst, 90 per cent conversion of Assam coal (about 80 per cent to liquids) were obtained with an impregnated iron catalyst. In batch experiments about 2 per cent iron was used by weight of coal, but in continuous operation this is likely to be considerably lower. This is perhaps a mjor gain.

A major break-through which has been claimed is the development of zinc chloride catalyst for hydrogenation of coal to gasoline. In fact, all American processes are directed towards production almost entirely of gasoline and the rest being either incidental or eliminated. Catalysts designed to produce light distillates and gasoline are, however, unsuitable for Indian conditions where production of naphtha has to be suppressed and production of middle distillates has to be maximized. At present, H-coal process is the nearest to the Indian requirements. It may be possible to modify the operating conditions to increase the middle distillate yields in the coal hydrogenation and in a later stage to minimize naphtha production. For Indian conditions, catalysts, operating conditions and processing techniques have to be developed or chosen which will give a product pattern most suitable for our markets.

Capital Costs

The capital costs for coal hydrogenation plants are heavy as they include bulk handling and preparation of coal, manufacture of hydrogen, steam generation and production of intermediates for petro-chemical production. It will be further inflated if mining and electricity generation were to be included. It is, therefore, not possible to directly compare the investments on coal conversion with natural oil exploration, production, transportation and refining. Costs of exploration, production at well-heads, piping to coastal parts, shipping in tankers, delivery and storage at the receiving port and refining and product storage may in some instances be quite heavy. Production of petro-chemical intermediaries are also normally not included in refineries.

The world average for cost of production of petroleum is perhaps of the order of Rs 600-750/t/yr. The costs of a modern refinery, including hydrotreatment and hydrofining on Indian soil is about Rs 200-250/t/yr of finished products. These figures add up to about Rs 800-1000/t/yr excluding petro-chemical complexes. Investments for primary petro-chemical units

producing intermediates only may be about Rs 1000/t/yr of naphtha feed. The costs are 'world average' costs for large petroleum cartels and individual costs in different counties or different well-heads may vary enormously. The cost of petroleum crude is, therefore, an arbitrary but statistical figure with reference to a fixed point of origin (e.g. Gulf of Venezuela or Gulf of Persia) plus transport costs to the point of reception. It is, therefore, impossible to compare these costs with the costs of a particular coal hydrogenation plant. In India for example, the costs of exploration and production of petroleum has been of the order of Rs 425 per tonne of proved resources to which has to be added refining costs bringing the total to about Rs 700 per tonne excluding petro-chemical intermediates. However, Indian costs of exploration and production per tonne of pay oil has so far been low. Additional oil discovered may not be so cheap. US costs are nearly three times as much. The future costs excluding piping and distillation and intermediate or chemicals manufacture may not be less than Rs 1000 per tonne of pay oil.

Compared to above, recent calculations for a $\frac{2}{3}$ gasoline and $\frac{1}{3}$ fuel oil plant from coal by the H-coal process indicate an investment of $ 130 millions for a minimum capacity of 30,000 BPD and $ 344 millions for a 100,000 BPD plant[10]. This represents a capital investment of Rs 780 ($ 104)/t/yr and Rs 525 ($ 83·5)/t/yr of finished products including chemicals or intermediates. The US estimates indicate that with coal at $ 3·25/t (with hydrogen perhaps at 20 ¢/MSCF), the cost of gasoline production may be of the order of 14-11·5 ¢ per gallon, competitive with current ex-refinery production costs of natural petroleum products. In these calculations, no credits for any chemicals are included except for byproduct ammonia and sulphur. Compared to these figures, earlier estimates in 1952 by the USBM and by EBASCO placed the figures at 18-19 ¢ per gallon. The War-time German costs were 190-235 RM per ton of finished products or about 0·56-0·7 RM per gallon.

The effect of scale of operations and modern technological developments on production costs are, therefore, obvious. The difference between per tonne costs of investments for 30,000 and 100,000 BPD plant can add up to investment costs for a modern petroleum refinery of 2 million tonne capacity.

One of the main differences between current concepts and War-time German plants is the scale of operations. Whereas the German plants had capacities ranging from 5000 to 10,000 BPD, modern estimates are based on 50,000-100,000 BPD. With modern developments in construction of high pressure vessels with layered plates, much larger reaction vessels are possible, which correspondingly reduce costs of compressors, pumps, motors, high pressure pipelines and valves and standby, etc., reducing the investments and production costs considerably. Better material of construction, advanced instrumentation and, therefore, control of operations, advanced designs, etc., all have contributed to lowering of costs by reducing probabilities of shut-down time and prolonging life of equipment. Superior catalysts having long and predictable life also contribute substantially to the lowering of costs.

As far as the Assam Project is concerned, although the coal conversion section is designed for 30,000 BPD, effect of scale-up in the refinery section has been obtained by combining with a natural crude refining with common facilities for hydrogen production and by combining a primary petrochemical complex. Due to its composition the Assam crude is best treated by techniques of hydrocracking and hydrofining for production of desired end-products. A further advantage of treating the syncrude and the natural crude together is that additional quantities of hydrogen become available from the off-gases of the combined refinery reducing requirement of external sources for hydrogen; a third benefit is additional production of aromatics as the Assam crude is also rich in aromatics; the fourth advantage is that the hydrocracked products obtained from syncrude and natural crude are complementary in nature and will probably enable less severe cracking of the syncrude than would otherwise be necessary; a fifth advantage of combining the two operations is that the effect of scaling up and hence lowering of production costs is shared by both syncrude refining and natural crude refining. As both syncrude and the Assam crude will produce substantial quantities of coke, fluid coking units can also be scaled up in size. Finally, benefits are gained in savings in piping, instrumentation and tankage costs and in combining the off-site facilities. These gains are substantial.

For the integrated coal-petroleum refinery and primary petro-chemical complex in Assam, the costs are estimated at Rs 2182 million or about Rs 740/t/yr for a 60,000 BPD plant including petro-chemical and carbo-chemical production and byproducts recovery which include production of ammonium sulphate, sulphur, calcined ash-less coke, etc. The costs, however, do not include mining which may add another Rs 220/t/yr oil (Rs 80-100/t/yr coal). Taking investment costs on coal mining, the total investment will be about Rs 840/t/yr of finished products from a mixed feed of 30,000 BPD of syncrude and an equal quantity of natural crude. However, since the coal costs are taken at production costs, as in the case of natural crude, no separate capital investments either for coal or oil are shown. Similarly, power generation costs are also not shown. Nearly 80 MW will be required. This also involves an additional investment of Rs 40/t/yr of mixed products bringing the total to Rs. 880/t/yr of mixed products. Again, since power costs are taken at sale values, the investment on this head is also not included in the estimate. However, no township or outside piping is included.

It will be observed, therefore, that even if mining and electricity generation costs are included, the investment costs per tonne of finished products, including chemical intermediates, is not very different for a combined coal-petroleum refinery from likely investment cost for exploration, production and refining of natural petroleum in India, if both were to meet similar market demands, quality- and quantity-wise.

The economics in petroleum production are based on world-wide averages where lucky strikes and gushers offset high costs of exploration and production in other areas. The average exploration and production costs of crude in USA is perhaps of the order of Rs 900 per tonne/year for a reservoir producing for 30 years, at say 1 million tonnes a year, compared to perhaps one fourth of this cost in Iran.

(to be concluded)

A. Lahiri & D. K. Mukherjee

References

1. *Report of Energy Survey of India Committee*, 1965.
2. Lahiri, A. & Sinha, N. C., *VII World Power Conference*, 1968.
3. Mukherjee, B. & Dutta, R., *Fuel*, **29** (1950), 109.
4. Mills, G. Alex, *I. & E.C.*, **61** (1969).
5. Private Communication, Office of Coal Research, USA.
6. Tsaros, C. L., Knabel, S. J. & Sheridan, L. A., IGT, Chicago, USA, A.G.A. Proj. No. IU-4-1, Aug. 1966.
7. *Coal Processing by Electrofluids* (Iowa State University of Science & Technology, Iowa, USA), OCR Contract No. 14-01-0001-479, April 1967.
8. Clacey, J. T. & Phinney, J. A., "Status of CO_2-Acceptor Process Development", paper presented at the AGA Production Conference, Buffalo, N.Y., USA, May 1965.
9. Mukherjee, D. K., Sen, M. M. & Lahiri, A., "Resources for Production of Synthetic Ammonia for Fertilizer Industry", paper presented at the Technical Symposium on Fertilizers in India, Mining, Geological & Metallurgical Institute of India, April 1968.

APPENDIX 1 — ANALYSIS OF SOME COALS OF UPPER ASSAM

	West Naga Hills		Upper Assam		NEFA East
	Disai	Nazira	Jaipur	Makum	Namchik
Air-dried Basis					
Moisture %	4·8-8·4	5·4	4·4-7·5	2·0-2·6	2·7-3·5
Ash %	1·1-1·8	3·0	1·4-10·0	1·9-5·9	1·6-4·0
Sulphur % (total)	1·1-1·4	4·3	1·3-6·5	1·7-5·8	1·1-2·7
Pure Coal Basis					
Volatile Matter	42·3-46·3	40·2	43·4-48·6	43·6-47·9	50·8-52·0
Calorific Value, kcal/kg	7195-7550	7835	7435-8030	8040-8385	8215-8250
Carbon %	75·8-77·4	80·8	74·4-80·0	79·3-83·1	80·6-80·8
Hydrogen %	5·2-5·7	5·6	5·0-6·4	5·7-6·4	6·5-6·7
Nitrogen %	1·5-1·7	1·6	1·3-1·6	1·0-1·5	1·2
Sulphur % (org.)	0·6-0·8	4·0	1·0-3·4	1·4-5·1	1·3-2·0
Oxygen (by diff.)	14·8-16·5	8·0	11·0-15·6	5·8-9·7	9·7-10·0
Caking Index	Non-caking	10	9 and less	20-35	
GK Coke Type	—	D	B-C	G_1-G_3	E-F

APPENDIX 2 — CLEANING CHARACTERISTICS OF SOME COALS OF UPPER ASSAM COAL CRUSHED THROUGH 38 MM. (1½ in.)

Seam and colliery	Sp. gr. of washing	Cleans		Sinks (a)		Middlings (b)	
		Wt. %	Ash %	Wt. %	Ash %	Wt. %	Ash %
		[38-0·42 *mm* (1½ *in.*-36 *mesh*) *size*]					
20 Ft, Baragolai	1·30	75·8	1·9	24·2	31·0	17·6	15·9
	1·40	86·7	2·8	13·4	48·7	6·8	26·5
	1·50	89·6	3·4	10·4	56·9	3·8	31·7
	1·60	91·5	3·9	8.5	63·5	2·0	36·5
	1·80	93·4	4·5	6·6	71·6	—	—
Top Coal, Baragolai	1·30	86·1	1·4	14·0	46·7	6·1	13·5
	1·40	90·3	1·7	9·7	63·5	1·9	26·1
	1·50	91·9	1·8	8·9	67·6	1·1	32·4
	1·60	91·6	2·0	8·4	70·2	0·6	38·6
	1·80	92·2	2·2	7·9	72·5	—	—
Bottom Coal, Baragolai	1·30	88·8	1·7	11·3	44·2	6·0	17·0
	1·40	92·1	2·0	7·9	59·1	2·6	27·0
	1·50	93·3	2·2	6·7	66·1	1·4	34·3
	1·60	93·9	2·4	6·1	70·2	0·8	40·0
	1·80	94·7	2·7	5·3	74·6	—	—
60 Ft, Baragolai	1·30	82·8	1·8	17·2	51·3	7·4	13·7
	1·40	87·8	2·1	12·2	68·9	2·4	25·2
	1·50	89·1	2·3	10·9	74·7	1·1	33·6
	1·60	89·5	2·4	10·5	76·6	0·7	37·5
	1·80	90·2	2·7	9·8	79·4	—	—
60 Ft, Tipong	1·30	82·3	2·4	17·7	32·1	12·3	14·6
	1·40	90·8	3·0	9·2	53·3	3·8	26·6
	1·50	92·7	3·4	7·3	62·3	1·9	34·4
	1·60	93·5	3·6	6·5	66·8	1·1	39·3
	1·80	94·6	4·0	5·4	72·3	—	—

(a) Total sinks at specific gravity of washing inclusive of middlings.
(b) Sinking at specific gravity of washing minus sinking at 1·80 sp. gr.

APPENDIX 3 — ANALYSIS OF SOME RAW AND CLEAN COALS OF UPPER ASSAM

	Baragolai top			Baragolai 60 ft			Tipong 60 ft		
	Raw	Cleans 1·40	Cleans 1·50	Raw	Cleans 1·40	Cleans 1·50	Raw	Cleans 1·40	Cleans 1·50
Proximate Analyssi, % (Air-dried basis)									
Moisture	2·8	2·4	2·4	2·1	2·1	2·2	2·3	2·1	2·2
Ash	8·1	1·7	2·1	9·7	2·3	2·8	9·3	3·1	3·3
Volatile Matter	37·5	41·9	41·6	39·7	42·6	42·7	42·2	44·6	44·2
Fixed Carbon	51·6	54·0	53·9	48·5	53·0	52·3	46·2	50·1	50·3
Ultimate Analysis, % (Unit coal basis)									
Carbon	82·2	82·3	82·8	82·7	82·2	82·7	82·2	81·9	81·9
Hydrogen	5·7	5·8	5·9	6·1	6·3	6·0	6·5	5·9	6·2
Sulphur (organic)	1·4	1·5	1·5	2·4	2·6	2·4	1·9	1·7	1·7
Nitrogen	1·4	1·3	1·4	1·3	1·2	1·2	1·4	1·3	1·3
Oxygen (by diff.)	9·3	9·1	8·4	7·5	7·7	7·7	8·0	9·2	8·9
Calorific value kcal/kg	8210	8250	8280	8320	8220	8270	8290	8285	8255

APPENDIX 4 — QUALITATIVE SPECTROGRAPHIC ANALYSIS OF RARE ELEMENTS IN ASSAM COALS (CHERRAPUNJI, LAITRYNGEW, LYNKERDEM AND THANGJINATH)

Elements sought in coal ash	Remarks	Elements sought in coal ash	Remarks
Ag	Not detectable	Cd	Not detectable
B	0·01-0·05%	Mo	do
Ba	Not detectable	Cu	0·01-0·1%
Be	Faint traces	Mn	0·01-0·1%
Ni	Not detectable	Cr	Faint traces
V	0·01-0·1%	Co	do
Zn	Faint traces	Ca	0·01-0·05%

(Unpublished work, CFRI).

APPENDIX 6 — COMPOSITION OF NATURAL GAS FROM ASSAM FIELD

Composition	% Vol. average	% Vol. range
Methane	90·0	86-94
Ethane	5·0	3-7
Propane	3·0	1-3·5
Iso-butane	0·5	0·2-0·0
N-butane	0·5	0·2-1·0
Higher hydrocarbons	0·5	0·2-1·0
CO_2	0·5	up to 1·0

Specific gravity, 0·64.

Gross calorific value, 1210 B.t.u./cu.ft. (10,800 kcal/Nm^3).

Net calorific value, 1018 B.t.u./cu.ft. (9720 kcal/Nm^3).

Sulphur content, 0·034 grains H_2S/100 cu.ft.; 0·018 grains C_4H_4S/100 cu.ft.

APPENDIX 5 — QUANTITATIVE ESTIMATION OF GERMANIUM IN ASSAM COALS

Sample particulars	Ash %	Ge ppm in ash
1. Cherrapunji, bottom seam	10·4	40
2. Lynkerdem Coalfield, bottom seam	7·9	48
3. Thangjinath Colliery, bottom seam	11·4	55
4. Laitryngew, bottom seam	11·2	115
5. Baragolai Coal (different seams)	1·9-15·9	90-120
6. Tipong Coal, 60 ft seam	18·0	75
7. Channel Overall Sample, lower seam, Nangwal-bibra colliery, Garo hills JHD/67/58)	15·6	500
8. Channel Overall, Nangwal seam, W. Darangiri coalfield (JHD/67/55)	6·5	600
9. Channel Overall (bulk samples), Nangwal seam, W. Darangiri coalfield (JHD/67/58)	4·0	600
10. Channel Overall, Nangwal seam at W. Darrangiri coalfield (JHD/67/58)	6·1	600

(Unpublished work, CFRI).

PROBLEMS OF MARKETING AND UTILIZATION OF NON-COKING COALS — A SYMPOSIUM

A SYMPOSIUM entitled "Problems of Marketing and Utilization of Non-coking Coal", the fourth in the series of symposia on Coal Mining Industry — Its Perspective and Problems, being jointly organized by Mining, Geological & Metallurgical Institute of India (MGMI), and the Joint Working Committee of various mining organizations with co-sponsorship of many organizations associated with coal, was held at Ranchi on 28 March 1970, with Shri Ranchor Prasad, Chairman, National Coal Development Corporation, as the Guest-in-Chief. The symposium was divided into three technical sessions, each dealing respectively with (i) Marketing, (ii) Utilization, and (iii) Diversification of Use and Creation of Demand.

First Session

The session, held under the Chairmanship of Mr V. P. Sondhi, discussed the paper "Mechanization of Burning Equipment for Widening the Horizon of Low Grade Slack Coal", by S. B. Sarkar and G. K. Moitra, Coal Board. Pointing to the growing accumulation of slack coal, particularly non-coking slack, the authors contended that increasing mechanization of the burning equipment only can solve the problem. While comparing hand-firing of coal with mechanical stoking in industrial practice, Sarkar and Moitra enumerated the following advantages for the latter:

(i) Output of steam from the boiler can be increased; (ii) coupled with an economizer, an increased thermal efficiency of 12-15 per cent can easily be achieved; (iii) in a battery of 5-6 boilers, labour can be saved to the extent of 50 per cent, and the work of the boiler attendant will prove much less arduous; (iv) loss of efficiency due to incomplete combustion can easily be avoided, with the elimination of smoke-nuisance; (v) wider scope of instrumentation or automatic control prevail to help and maintain a constant rate of evaporation and pressure; and (vi) wider range of quality and coal in slack size can be accommodated, including certain amount of fluctuations in their quality. Discussing the economics of conversion of hand-firing equipment to mechanical means, the authors showed that for a Lancashire boiler of 6000 lb/hr evaporation capacity, the annual saving would vary from Rs 21,600 to Rs 36,000, depending on the landed price of the coal. Indicating the advantages of PF firing, the authors felt that more research work should be carried in this direction and every effort should be made to use PF firing in small boilers.

Second Session

This session, devoted to the utilization aspect of non-coking coal, was presided over by Mr S. K. Nargundkar, Executive Adviser, East India Coal Co., Jealgora, Dhanbad. Six papers were discussed in the session.

S. B. Sarkar of Coal Board, in his paper indicated that the use of inferior coals was restricted to the process of combustion only, be it for power generation, process steam raising, railway locomotive firing or direct firing in the kilns and furnaces. For greater use of non-coking coal and washery byproduct fuel in the future for power generation, he said that future power plants should be located either near the pit head or at such places where the delivered cost would be low and with adoption of modern high tension transmission, such projects would be economical.

For expanding the market of non-coking coal in the field of process steam raising and transport sector, Sarkar stated that the only way was mechanization of the burning equipment and that a certain degree of mobility and flexibility in marketing was also necessary to popularize more use of coals. He suggested: (i) Centralized conversion of coal to gas as the heating medium in the industrial belts and its distribution by pipeline network; and (ii) hydraulic transportation of coal within economic distance for PF firing and setting up of coal-based complexes.

S. C. Brahma of Bihar State Electricity Board gave a general account of the problems associated with handling, storage,

maintenance of efficient combustion schedule, etc., with case studies of the operating conditions of Neyveli Thermal Power Station and Patratu Thermal Power Station.

For Neyveli Thermal Power Station, using lignite for power generation, the difficulty in storing was due to deterioration in physical and chemical properties as well as spontaneous combustion of lignite. The problem concerning drying of lignite was solved by drying first in the crusher, then in the hammer mill shaft and finally by mixing the lignite with combustion gases having a temperature of about 900°C The last step needs careful handling as the system is exposed to explosion hazards. Slag formation by burning of the lignite was prevented to some extent by controlling the supply of secondary air for which the capacity of the forced draft fans had to be increased.

During the early stages of operation of Patratu Thermal Power Station, troubles due to slag formation and deformation of burner tips and screen superheater tubes, as described by the author, were obviated by suitable modifications. Problem of dust was mitigated by water spraying, although there was disadvantage of adding excess moisture in many cases.

For avoiding frequent changes in furnace operation schedule, arising out of the changes in the characteristic and the grade of the fuel, Brahma suggested two ways. A schedule may be prepared much in advance for burning of a particular grade of fuel during a specific period so that the authorities may be advised to allocate the fuel accordingly for that period. Alternatively, coals may be blended in the coal storage yard to prepare a ready stock of fuel having consistent character.

In the next paper S. R. Ghosh of Bihar State Electricity Board dealt elaborately with the working of the Patratu Thermal Power Station where trouble was experienced due to slag formation by burning fuels indiscriminately.

Consumers' problems regarding coal purchase and utilization were highlighted by S. Chakraborti of West Bengal State Electricity Board. He alleged that a consumer always received lesser amount of coal than that mentioned in railway receipts. The causes were attributed to either pilferage during transit or underloading at suppliers end. He urged the Railways to try to stop such pilferage and the suppliers not to underload. He was in favour of sharing the responsibility of losses equally among the purchaser, supplier and the Railways. Another problem faced by the electricity undertakings, according to him, was the irrational movement of rakes by the Railways. Chakraborti pleaded for rational movement as per the requirements and unloading capacity of the purchasers.

Non-supply of properly sized coal was another problem to the consumers. Suppliers should pay attention to the proper sizing of the coal as per contract.

Erosion in PF fired boilers could be minimized if the engineers and designers jointly find out the best type of spacing, proper metal for the tubes and furnace volume, opined Chakraborty. The experience from the existing boilers should form the guidelines. Bunker fire and commercial utilization of fly ash were the other problems referred to by him.

In the next paper, D. Basu of NCDC indicated some utilization avenues for non-coking coal. Production of processed smokeless domestic fuel either by low temperature carbonization or stoker carbonizer and integrating with the production of 'formed coke' (developed by CFRI), he said, would even utilize the fines produced in l.t.c. The 'formed coke' also possessed the potential of being used as processed metallurgical fuel. However, he felt that large-scale plant trials should precede commercialization of such processes. Referring to the Government's plan to set up three coal-based fertilizer plants, Basu observed that production of fertilizers should be an important avenue for the utilization of non-coking coals.

The third route to utilization as indicated by Basu was conversion of coal to chemicals and oils via pyrolysis, direct hydrogenation and Fischer-Tropsch synthesis. He highlighted the success of the 'Sasol Project' of South Africa, the work of US Bureau of Mines, OCR and Consolidation Coal Company.

K. S. R. Chari, presenting a paper on behalf of the Ministry of Mines & Metals, referred to the consumption pattern of non-coking coal and indicated possible areas where the consumption can be stepped up. He observed that in the field of power production, although the percentage contribution of coal as such was expected to diminish, in absolute terms, however, it would increase.

Discussing the role of non-commercial fuels in the total energy programme, Chari stated that although the share of non-commercial fuels was decreasing (from 75 per cent in the beginning of Fourth Five Year Plan to 50 per cent in the present plan), the quantity of firewood registered an increasing trend. To conserve firewood, popularization of soft coke was the dire need. To implement this, he said, cooperation and coordination among the industry, Railways and the State Governments were needed.

Chari also referred to the rapidly increasing dependence on oil. He was hopeful that the growing demand for petroleum projects will intensify the drive for commercializing the production of liquid fuel from coal. This is an area in which the CFRI is also doing considerable research.

Chari pointed out that the lowering of take off coal by Railways is the result of increasing dieselization of railway locomotion. In view of the ever widening gap between the availability and demand of petroleum crude, he said, the dieselization policy should be such as to keep down to the minimum the import of crude. Dependence on electicity for traction power, he felt, would have created a demand for coal.

The acceptance of coal as feed stock for fertilizer manufacture was welcomed by Chari as an achievement in the utilization of non-coking coals.

Making a reference to 'formed coke', and particularly to the work of CFRI in this respect, Chari also expressed that if it could replace partially or wholly the hard coke, a new vista in the utilization of non-coking coal would be opened up. It would then not be necessary to restrict the setting of steel plants only near localities bearing coking coal.

Third Session

The concluding session of the symposium which dealt with Diversification of Use and Creation of Demand for Non-coking Coals, was presided over by Dr A. Lahiri, Director, CFRI. Two papers were presented and discussed in the session.

V. K. Seth, representing Joint Working Comittee, dwelt on the growing competition that coal is facing with other fuels in the overall energy picture. Either to maintain the present quantum of contribution of coal to total energy needs or to improve upon it, coal has to be competitive with other fuels, Seth contended. According to him, elementary measures like lagging, thermal insulation, recovery of condensate heat, economical loading of heat consuming plant and the use of steam at lowest possible pressures might help in attaining greater efficiency in coal combustion without much capital expenditure. Use of boiler feed-water economizers and mechanical stokers are other means to increased efficiency. Other points made by Seth are: (i) The electricity generating plant should be erected near the energy resources as the delivered cost of fuel in India is very high, of the order of 70 per cent of the cost of generation. Due to the increased consumption of power in coal mines, due to increased adoption of coal washing, screening, winding, ventilations, pumping, etc., use of byproducts of washing for power generation might increase. Also, long distance transmission at high voltage provides considerable economy. (ii) The falling demand of coal by the Railways due to their increased dieselization can be checked if direct transition from steam to electricity is made. This changeover will increase the demand of coal for power generation. (iii) If coal cannot compete with liquid fuel as such, it can do so when converted to liquid fuels. In this connection he recorded his high appreciation for the work of CFRI. (iv) The demand of non-coking coal even in the iron and steel industry can be increased either by blending or by manufacturing 'formed coke' suitable for metallurgical application. He made reference to the considerable work done by CFRI. Coal will find increasing use in the domestic sector, carbochemicals industry and agriculture. In agriculture, the coal would be used as fertilizers and in the food industry, coal derived hydrocarbons will serve as food for the microbes producing protein. For this to happen, large-scale economic mining of coal is vital.

Mr Hassan of NCDC bitterly criticized the present coal marketing policy for sudden booms and slumps in the demand of coal. In order to forestall such irregularities, he said, a sound and systematic marketing policy based on sound statistical knowledge and research expertize is essential. For creation of demand, the author felt, the initiative should come from the producers and not from the consumers. To increase

the demand of soft coke for example, he proposed that the producers should form an association whose duty would be to popularize soft coke among the villagers through propaganda cum demonstration. In this venture, the Railways can also contribute by reducing the freight for long haulage, providing covered wagons, regular supply of wagons in accordance with the need, etc.

Mr Hassan also stressed on the need of educating the consumers on better utilization and safe storing of coal and the need for close cooperation of the coal producers, manufacturers of consuming equipment and the consumers to enhance the demand of coal.

R. S. Saha & S. R. R. Rao

Editorial — *Contd from page* 49

for exchange. This alone should induce us to take a hard look at the possibilities for synthesizing petroleum or its products. After all, this was done in Germany on a large scale during the war. Interest in the subject has been revived, strangely enough and in a big way, in the land of oil and gas — the United States of America. For reasons of security, if not for sheer existence, the United States has launched a major R & D programme for conversion of coal to oil. Necessity is the mother of invention, but the America's absorbing interest in coal conversion has basically affected their outlook on coal. As Dr Henry R. Linden stated in his Address on being presented with the Henry R. Storch Award of A.I.Ch.E.:

> "In essence, we thought coal to be simply very dirty petroleum. As chemical, petroleum and gas engineers, rather than old style industrial chemists and geologists, we concentrated on making coal just another hydrocarbon fuel. . . coal is coal. It is black, mostly carbon, maybe even beta-graphite! In other words, we approached coal with the Dulong formula philosophy. Although coal had a lot more oxygen than petroleum, we get rid of that by means of the net hydrogen content. The sulphur and nitrogen contents of coal and petroleum are not too different, so that if you can practically ignore them in petroleum, there is no reason to worry about them in coal. Moisture and ash are obviously nothing to worry about since they are just inert minerals which can be computed into oblivion!"

Behind this light banter there is a major thermodynamic concept and a range of industrial experience in the field of chemical technology and in particular petroleum technology as well as material and process development which enable US scientists to predict confidently commercial conversion of coal to oil in that country before the '80s. Hard-headed business organizations and oil companies (and the US Government agencies) have not only invested enormous sums in R & D on coal conversion but have also invested vast sums in ensuring raw material resources. It is reported that more than 50 per cent of the coal resources and more than 25 per cent of the producing areas of that country are now owned by erstwhile oil interests. The coal conversion programme is not limited conversion of coal to gasoline, but also to chemicals as well as substitute for natural gas.

There are several ways to convert coal into petroleum hydrocarbons. Coal may be carbonized to produce tar, e.g. by low temperature carbonization. The residue, char or coke breeze, may be used for power generation or for domestic or for other industrial purposes. The carbonization gases contain enough hydrogen to convert the low temperature tar into petroleum hydrocarbons. The scope is, however, limited as only about 10 per cent by weight of coal is converted to tar by normal methods of carbonization either in fluid bed or in fixed bed. Integrated with major power generation projects, this route can be of interest in future.

A second way, also developed in Germany during the war, and indeed being currently operated on a commercial scale in South Africa, is the Fischer-Tropsch synthesis which involves gasification of coal (as being proposed for fertilizer manufacture in India) for production of carbon monoxide and hydrogen (synthesis gas). These elementary building blocks can produce under appropriate conversion techniques (with catalysts) a wide range

(*Continued on p.* 88)

PHENOXYACETIC ACIDS AND THEIR DERIVATIVES AS SELECTIVE WEED KILLERS

Introduction

DERIVATIVES of aryloxyacetic acids have recently attracted considerable interest as plant hormones and selective weed killers, although they were discovered as early as 1942 by Slade *et al.*[1]. To distinguish them from human hormones, they were termed as phyto-hormones by Thimann[2] in 1948. The phenomena for their specific selectivity in killing undesired plants when present in association with the most economical varieties was first of all observed by Zimmerman and Hitchcock[3] while working at Boyce Thompson Institute. They found that most of the phenoxy derivatives can successfully eliminate broad-leaved plants (dicots) without damaging narrow-leaved species (monocots).

Later work has presented a host of chemicals with selective plant hormonal activity and has stimulated the growth of new chemical industries.

Important Phenoxy Compounds

Phenoxyacetic acid itself has practically no growth regulating properties but marked activity is shown by its 2-chloro, 4-chloro, 2:4- and 3 : 4-dichloro and 2 : 4 : 5-trichloro derivatives, but 2 : 6- and 3 : 5-dichloro compounds have negligible activity[4]. The more important ones commonly used in agricultural practices are 2 : 4-dichlorophenoxyacetic acid (2,4-D); 2-methyl-4-chlorophenoxyacetic acid (MCP, MCPA, methoxone); 2-methyl-4-chlorophenoxybutyric acid (MCPB); 2-methyl-4-chlorophenoxypropionic acid (MCPP); 2,3,5-trichlorophenoxyacetic acid and sodium 2,4-dichlorophenoxy ethyl sulphate (natrin).

2,4-D is characterized by its effective weed control at low concentrations, and its ability to be translocated within the plants. Further, none of the 2,4-D group of compounds is appreciably toxic to higher animals and they are non-corrosive to machinery. Moreover, the 2,4-D is particularly useful in the control of broad-leaved weeds in cereal crops. Since 2,4-D has got low solubility in water, various derivatives like salts of ammonium, potassium, sodium and amines are used in actual practice. Esters of 2,4-D have also found wide application.

2 - *Methyl* - 4 - *chlorophenoxyacetic acid*[5] (MCPA, methoxone) is highly successful for the control of weeds in cereals, grasses, barley, wheat, oats, etc.

2 - *Methyl* - 4 - *chlorophenoxybutyric acid* (MCPB) is more selective in action than MCPA in the control of weeds in cereals, clovers and certain varieties of peas.

2-*Methyl*, 4-*chlorophenoxypropionic acid* (MCPP) is mostly used to control the weeds like cleavers (Galium aparine) and many other weeds in cereal crops.

2,4,5-*Trichlorophenoxyacetic acid* (2,4,5-T) and similar formulations are used to kill brush, brambles (pricky shrub, e.g. black berry) and other woody plants. Like 2,4-D it is also available in the form of its alkali, amines and ester salts.

Some other compounds like sodium, 2,4-dichlorophenoxy ethyl sulphate (crag 1, ses, 2, 4-DES), 2,4-dichlorophenoxy ethyl benzoate (sesin or 2,4-DEB) and sodium 2,4,5-trichlorophenoxy ethylsulphate (Natrin or 2,4,5-TES) are closely related to 2,4-D except that they are applied to soil instead of to foliage.

Several other phenoxy type compounds have been prepared and tested as herbicides but none of them has attained wide use. Among such compounds are 2 : 4-dichlorophenoxypropionic acid; 2-(2,4,5-trichlorophenoxy)-propionic acid (Silvex); *p*-chloro phenoxyacetic acid; 2,5-dichlorophenoxyacetic acid; 3,4-dichlorophenoxypropionic acid (3,4-DP) and 2-(2,4,5-trichlorophenoxy)-ethyl sulphate.

A number of new derivatives of 2 : 4-D are undergoing field trials, particularly in USA and UK. Most of them have had some screening and testing in the laboratory. Among such compounds are 2-(2,4,5-trichlorophenoxy) ethyl, 2,2-dichloropropionate (Erbon) and tris-(2,4-dichlorophenoxy ethyl) phosphite (EH/3Y9).

Preparation of Phenoxy Derivatives

Four methods are commonly used.

1. By condensation of phenol and chloroacetic acid (C. Frederick Koelsch)[6,7]: The

phenol and chloroacetic acid in the form of their sodium salts are allowed to undergo condensation at 100°C for one hour. The phenoxyacetic acid formed in the solution is extracted with ether and purified by recrystallization from hot water.

The yield by this procedure is reported as 33 per cent of theoretical. Various modifications[8,9] have been made by several workers to improve the yield. The best yields have been obtained by Josef Vahala *et al.*[10] who obtained 90 per cent yield. These workers stressed the necessity of maintaining the *p*H at 8·8, close control of the proportion of the reactants and duration of heating.

2. By condensation of phenol and ethyl chloroacetate in dry acetone in presence of sodium carbonate: The ethyl phenoxyacetate thus formed is hydrolysed with aqueous caustic potash to liberate free phenoxyacetic acid[11].

Some modifications[12-14] of this method have been suggested, such as condensation of phenol and ethyl bromo acetate. This method gives about 56 per cent yield for the two stages.

3. Phenol is reacted with vinyl acetate giving 1-phenoxy ethyl acetate at 25°C in the presence of copper resinate, mercuric acetate and H_2SO_4. The product on hydrolysis gives phenoxyacetic acid[15].

4. By condensation of phenol and chloroacetonitrile (J. M. Mc Manus & Robert, 1959)[16] : Phenol and chloroaceto nitrile are heated under reflux for 8 hrs. in acetone in presence of sodium carbonate. The phenoxyaceto nitrile[17] thus formed is hydrolysed with 25 per cent sodium hydroxide solution to give phenoxyacetic acid.

Chlorination of Phenoxyacetic Acid

Four methods are available for the chlorination of phenoxyacetic acid in 2 and 4 positions.

1. Using aqueous sodium hypochlorite (C. Y. Hopkins & Mary J. Chisholm, 1946)[19,20].

Phenoxy acetic acid is dissolved in dilute alkali and reacted with sodium hypochlorite solution at ordinary temperature. The yield is 75 per cent of theoretical[18].

2. By chlorine gas: A solution of phenoxyacetic acid in glacial acetic acid containing traces of I_2 or Fe as catalyst is chlorinated with gaseous chlorine first at 20° and then at 60°C. The yield is 82 per cent of the theoretical.

3. By dichlorocarbamide: The chlorine is first of all reacted with urea at 0°C to form dichlorocarbamide. The dichlorocarbamide formed is reacted with phenoxyacetic acid with addition of HCl. The yield is 55 per cent of the theoretical[21].

4. Chlorination by sulphuryl chloride: Phenoxyacetic acid and sulphuryl chloride and glacial acetic acid are mixed and the temperature of the mixture is raised from 0 to 75° and maintained at 75° till the gas evolution ceases. The compound is recrystallized from benzene. The yield is 74 per cent of the theoretical yield of 2:4-D[14].

Structure and Physiological Activity

The first comprehensive studies in the relation between structure and physiological activity of phenoxy type of compounds was made by Koepfli, Thimann and Went[22]. From a study of a range of compounds in the pea curvature test they concluded that the following properties must be possessed by a weedicide:

(1) ring system as nucleus; (2) at least one double bond in the ring; (3) a side chain possessing a —COOH group or a group easily convertible into —COOH, such as ester, amide, nitrile or aldehyde; (4) at least one C atom between the ring and the —COOH group in the chain; and (5) a particular relationship between the ring system and the —COOH group.

Later studies revealed that these requirements were not acceptable. Thus there are compounds fulfilling these requirements but are inactive and vice versa.

Veldstra[23] modified the requirements stating that the essential features were a ring system with high surface activity and carboxyl group in a very definite spatial position with regard to the ring system.

Thus a variety of concepts emerged which can be classified under the following heads.

Nature of the Ring — There has been much inconclusive debate on the significance of the ring and its double bond. It has been found that the presence of a single double bond in the ring can confer activity to the molecule, provided its position is adjacent to the side chain (Went, 1949).

Several theories have been put forward to explain the importance of unsaturation

in this connection. The view of Commoner and Thimann[22] (1941) that a reversible oxidation reduction property of the double bonds might enable auxins to act as respiratory catalysts was disputed by Veldstra (1944). According to him the degree of unsaturation influenced the surface activity of the molecule.

Nature of the Side Chain — It has been shown that compounds in which the —COOH group is separated from the ring by an odd number of carbon atoms possessed activity, whereas compounds with an even number of methylene groups had negligible activity. Synderholm and Zimmerman (1947) suggested that oxidation mechanism could explain this difference of activity. By such means, i.e. by oxidation, acids with an odd number might be converted to the active acid homologues, whereas those containing an even number might yield the parent phenol with no growth regulating activity.

Terminal —COOH *Group* — It is observed that most of the herbicides have a —COOH group or other groups which could be converted to —COOH in the plant tissues. In many cases, these groups other than —COOH induce less activity, though this is not always the case. A specific enzyme, necessary to effect the conversion, must be present in the plant tissues. A number of indole compounds with different terminal groups have also been studied[24].

Replacement of the —COOH *Group* — It is seen that compounds prepared by replacing —COOH by other acidic groups still possess herbicidal activity. The effects on activity of replacing the —COOH group by other acidic groupings like sulphuric, nitrophosphoric and arsonic groups, have been investigated by a number of workers. The results indicated that their effect is considerably inferior to that of the —COOH group.

It is of interest to note that certain phenoxythiocarboxylic acids, in which the —COOH group is replaced by —COSH, can show high activity (Bustron, 1956). The replacement of —COOH group by amino group has also been studied[25].

Substitution in the Side Chain — The substitution of oxygen in phenylacetic acid to form phenoxyacetic acid eliminates the feeble activity of the former. The introduction of oxygen in alpha-naphthylacetic acid reduces the activity but in case of beta-naphthylacetic acid the activity is increased.

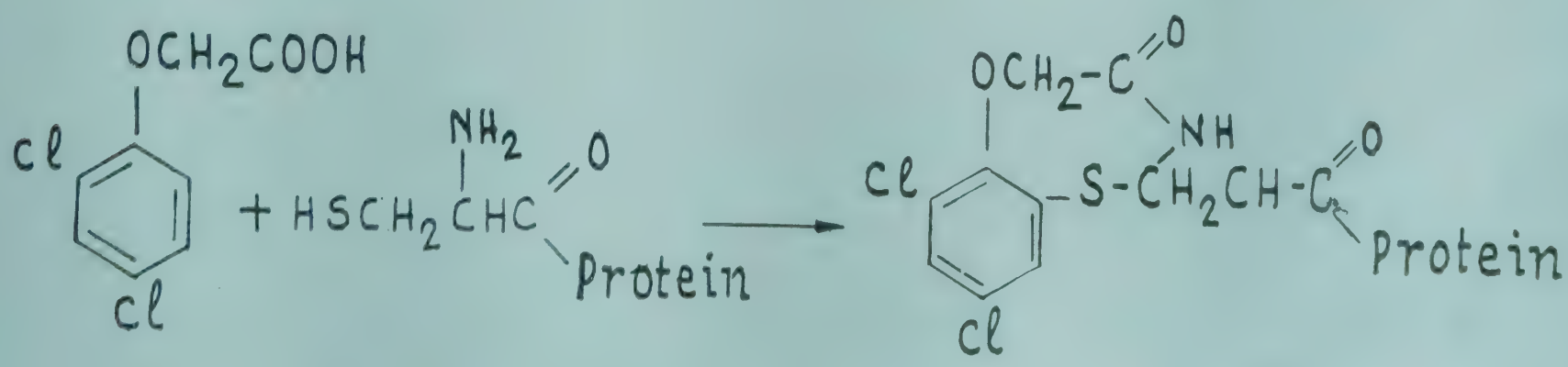
Replacement of the oxygen of phenoxyacetic acid by sulphur, SO- and SO_2 groups lowers the activity.

Position of the Side Chain — In growth substances derived from indole and naphthalene, the position of the side chain is very important, e.g. indole 3-acetic acid is active whereas indole 2-acetic acid is almost inactive. Similarly, 2-naphthoxyacetic acid is active and 1-naphthoxyacetic acid is negligibly active.

Unsaturation in the Side Chain — Unsaturation in the ring is not an absolute requirement for growth regulating activity[26]. Thus carboxy methyl dimethylthiocarbamate and some of its analogues possess growth promoting activity, even though they do not possess an unsaturated ring system. Among such compounds having unsaturated side chain, *cis*-compounds are active while *trans* are inactive.

Substitution in the Ring System — A number of theories have been put forward to account for the low activity of the compound having substituents at 2 and 6 positions (both ortho positions). Muir and his coworkers[22] suggested that the reacting group within the cell might be the cysteinyl group of the protein and reacts with the growth substances as is shown below.

Hence the presence of a free ortho-position in the growth substance is essential. But it has been found that inactivity in phenoxy acids substituted in the 2,6-positions is not true in all cases, e.g. the introduction of methyl or ethyl group in the side chain of 2,6-D leads to an increase in activity[27].



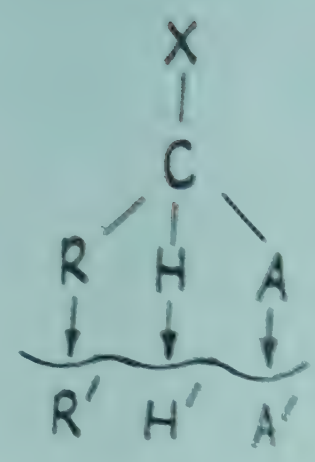
In connection with the substitution in the ring, following points are noteworthy. (N. N. Melnikov)[28]:

(1) Halogenation of phenoxyacetic acid or its derivatives cause an increase in activity of the compounds.
(2) A trihalogen derivative with the 3rd halogen in the 4-position has greater activity than the dihalogen derivative.
(3) During the transition from the chloro to the bromo derivatives, the activity of the compound decreases.
(4) Amides of phenoxyacetic acids have less activity than the acids.
(5) The activity of the anilides is still lower.
(6) 2-Phenyl-4-halophenoxyacetic acid has greater activity than its isomer 4-phenyl 2-halophenoxyacetic acid.
(7) 2-Phenyl-6-halophenoxyacetic acid has less activity than phenoxyacetic acid containing halogen in the position 4.
(8) 4-Benzylphenoxyacetic acid and its derivatives are comparatively less active than the 2-me-phenoxyacetic acid and its halogen derivatives.

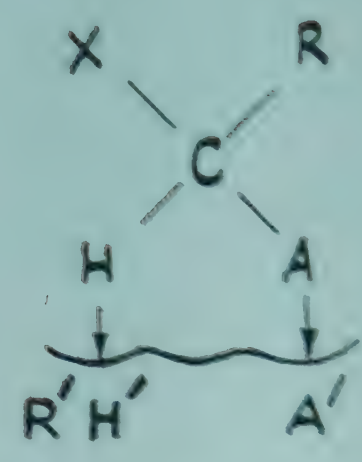
Theories Regarding the Activity of Phenoxy Derivatives

The phenoxy derivatives have unsaturated ring system, α-hydrogen, and carboxyl group. Such aryloxy acids were resolved by Smith[23] into (+) and (−) enantiomorphs. He found that in all the tests the (+) isomer showed high activity whereas little, if any, was shown by the (−). The racemic acid was found to possess intermediate activity. These differences in relative activity were due to the differences in the movement of the respective molecules within the tissues. This hypothesis has been developed by Wain and his coworkers[29] (1951) based on the mode of action of various enantiomorphs of aryloxy acids and low activity of (−) form. It is suggested that growth regulating activity in the aryloxy acid molecules is dependent on the presence of three 'essential' groupings, namely unsaturated ring system (R), α-hydrogen (H), and carboxyl group (A). Further, when these molecules reach the primary site of 'action' which is regarded as some boundary surface within the plant cells, each becomes associated with specifically placed cell receptor groupings (R′, H′, A′).

It is evident that only the stereo isomer will show growth response because on



Three-point contact
(active response)



Two-point contact
(no response)

R = benzene ring; H = α-H_2; A = carboxyl group; ~~~ = primary site of action on the boundary surface of plant cells

approaching the boundry surface, it can get oriented in such a position as to provide its three groupings in the correct relative positions. In case of (−) isomer, the activity is negligible as only two groups come in contact with the receptor centres.

These considerations led Smith *et al.*[29] (1952) to suggest that the inactive isomer (−), when present in large excess, might depress the activity of the active form (+) by competing for the active receptor

Johnson *et al.*[22] (1955) extended the three-point contact theory of Smith and Wain to explain the activity of aryl and aryloxy alkane carboxylic acids.

Conclusions

Very little basic information is available on the chemistry and mode of action of chemical weed killers.

The chlorophenoxy compounds have auxin-like properties but the mechanism of auxin action is yet to be understood. Hence, the present trend is to study the biochemistry of these compounds so that intelligent search for more and better herbicides can be made.

The aim of the present research is for development of more specific weed killers, and more effective herbicides. Fundamental research on mechanisms of selectivity of herbicides requires attention in order to reduce the large amount of work now required to find and prove a new chemical for its use as weedicide or herbicide.

M. S. Anand, C. S. B. Nair
& A. N. Basu

References

1. Aldrin, A., *Selective Toxicity* (John Wiley & Sons Inc., N.Y.), 1951, 4.
2. Audus, L. J., *Plant Growth Substances* (Leonard Hill Books Ltd., Lond.), 1959, 16.
3. Kerk, R. D. & Othmer, D. F., *Encyclopedia of Chemical Technology* (Interscience Publishers Inc., N.Y.), **15** (1956), 18.
4. *Discovery.*, **VII** (1946), 126.
5. Crafts, A. S., *Advances in Pest Control Research* (Interscience Publishers Inc., N.Y., Lond.), **I** (1957), 39.
6. Frederic, Kolisch C., *J. Am. chem. Soc.*, **53** (1931), 304.
7. *Organic Reagents for Organic Analysis* (Hopkin & Williams-Chemical Publishing Co. Inc., Brooklyn. N.Y.), 58.
8. Norman, Hayes. V., Gerald, E. K. & Branch., *J. Am. chem. Soc.*, **65** (1943), 1555.
9. Eckstein, Z., Ciepienko, W., Grochowski, E., Sobotka, W. & Zaszczynska, B., *Chem. Abstr.*, **52** (1958), 3242g.
10. Josef Vahala., Jiri Sponsar. & Joromir Weigner., *Chem. Abstr.*, **59** (1963), 11310b.
11. Brettle, B. R., *J. chem. Soc.*, (1956), 1891.
12. Kerk, R. D. & Othmer, D. F., *Encyclopedia of Chemical Technology* (Interscience Publishers Inc., N.Y.), **10** (1953), 723.
13. Wawzonek, S. & Wang, S. C., *J. org. Chem.*, **16** (8) (1951), 1272.
14. Melvin Fields., Seymour Rothchild & Morris, Leafer. A., *J. Am. chem. Soc.*, **74** (1952), 3435.
15. Corson, B. B., Tiefenthal, H. & Heintzelman, W. J., *J. org. Chem.*, **21** (1956), 371.
16. Manus, Mc J. M. & Robert, Herbest. M., *J. org. Chem.*, **24** (1959), 1464.
17. Powell., Adams., *J. Am. chem. Soc.*, **42** (1920), 646.
18. Haskelberg, L. J., *J. org. Chem.*, **12** (1947), 426.
19. Hopkins, C. Y., Marry, Chisholm. J., *Canad. J. Res.*, **24B** (1946), 208.
20. Mc Rae, J. A. & Hopkins C. Y., *Canad. J. Res.*, **7** (1932), 248-57.
21. Ghosh, A., *J. Indian chem. Soc.*, **28** (3) (1951), 155.
22. Wain, R. L., *Advances in Pest Control Research* (Interscience Publishers Inc., N.Y., London), **II** (1957), 263.
23. Wain, R. L., *Sci. Progr.*, **44** (1964), 604.
24. Brown, J. B., Henbest, H. B. & Jones, E. R. H., *J. chem. Soc.*, (1952), 3172.
25. Wood, J. W. & Fontaine, I. D., *J. org. Chem.*, **17** (1952), 891.
26. Kerk, G. J., Vander, M., Raalte., Van, M. H, Sijpesteijn, A. K. & Veen R. Vander., *Nature*, **176** (1955), 308.
27. Osborne, D. J., Sudzuki, F. & Novoa, S., *Nature*, **174** (1954), 742.
28. Melnikov, N. N., Turetskaya, R. K. & Baskakov, Yu. A., *Chem. Abstr.*, **49** (1955), 16305a.
29. Wain & Coworkers., *Proc. roy. Soc. (Lond.)*, **B139** (1951), 118.

ASSOCIATESHIP EXAMINATION OF THE INSTITUTION OF CHEMISTS (INDIA), 1971

The Twenty-first Associateship Examination of the Institution of Chemists (India) will be held in November 1971. The last date for Registration is 30 November 1970. The Examination in Group A (Analytical Chemistry) is divided into the following eleven sections and each candidate will be examined in two of them according to his choice as approved by the Council, in addition to the General Chemistry including Organic, Inorganic, Physical and Applied Analytical Chemistry: (1) Analysis of Minerals, Silicates, Ores and Alloys; (2) Analysis of Drugs and Pharmaceuticals; (3) Analysis of Foods; (4) Analysis of Water and Sewage; (5) Biochemical Analysis; (6) Analysis of Oils, Fats and Soaps; (7) Fuel and Gas Analysis; (8) Analysis of Soils and Fertilizers; (9) Analysis Connected with Forensic Chemistry; (10) Analysis Connected with Leather Chemistry; (11) Analysis Connected with Textile Chemistry. The Examination is recognized by the Government of India as equivalent to M.Sc. in Chemistry for purposes of recruitment of Chemists.

Further enquiries regarding this and for Membership may be made to the Honorary Secretary, Institution of Chemists (India), Chemical Department, Medical College, Calcutta 12.

Spotlight

ON SCIENTIFIC ACTIVITIES

Coals of Madhukunda-Poradiha Area, Raniganj Coalfield*

The notified Madhukunda block and the adjacent Poradiha area lie in the south-western corner of the Raniganj coalfield, bounded in the north by the river Damodar and the group of hills Panchet (2110 ft), Gorangi (953 ft), Biharinath (1481 ft), demarcate the southern limit of the area (Plate 1). In recent years the deep-drilling projects were undertaken in the area by the GSI, IBM and NCDC, chiefly to ascertain the continuity of the well-known seams of the Raniganj Measures [viz. Dishergarh (R-IV), Sanctoria (R-II), etc.], with a view to maintaining an adequate production of the blendable coals in future years and to assess the available reserve of coals from this virgin area. The drilling data as well as those on chemical properties of coals obtained at the Coal Survey Laboratory (CFRI), Raniganj, helped to evaluate the hitherto little known geological set-up and structural pattern of the area.

The presence of almost all the coal seams of the Raniganj Measures have been established in this part of the field except the VI seam (Sripur seam), which has not developed in the area. Among these, five seams R-X, R-IX, R-VIII, R-V and R-IV are more than 1·0 metre thick. A comparative study of the coal properties of the respective seams (Table 1) as obtained through analyses in the Coal Survey Laboratory, CFRI, and the trend of variation of isochores and isocarbon lines of these two adjacent sectors reveal a significant deterioration, both in thickness and rank characteristics of coals of the respective seams from north to south as well as from west to east. Particularly, the Dishergarh seam (R-IV) exhibit carbon content of 83·5-85·0 (on unit coal) with 15 and above caking index in the western sector; corresponding values in the eastern sector are 82·0-83·5 (on unit coal) with weakly caking property of coals.

The present area lies very close to the Main Southern Boundary Fault. The recorded throw of the fault near the Panchet hill is about 9000 ft. Obviously, the immense effect of this huge displacement, although it occurred contemporaneously with the sagging of the main basin, appears to be the main cause of the structural complexity and obliteration of the stratigraphical sequence in the area. The large number of deep-boreholes in the area clearly reveal that the basal strata of the western sector (Madhukunda area) being close to the Panchet hill, has undergone considerable rolling and buckling into a number of synclines and anticlines, e.g. Murulia Alkusha Syncline deleneated by the Deoli fault, etc. A number of large faults of considerable magnitude have further complicated the structure of the area (Plate 1).

In the eastern sector (Poradiha area) in between Gorangi and Biharinath hills, beds are exposed in an elongated gentle dome, dipping towards north. A borehole (RN-14) close to the structure met with Dishergarh seam (R-IV) at a shallow depth (212 metres), observation indicate, the cropping out of the lower Raniganj Measure seams in the near vicinity, as a southern limb of the main basin. Accordingly, over the 'Dome structure', Iron Stone Shales (Barren Measure) are also expected to crop out, and the underlying Barakar Measures of the area appears to be present within approachable depth. Further east, along the Chakboga Jor, the trend of the seam outcrop is NS and the beds are dipping N-NNW indicating a closed basin (Plate 1). Contrary to expectations, the entire area is almost free of any major igneous intrusives.

*Based on a paper entitled "Mode of Occurrence and Properties of Coal Seams in and around Madhukunda-Poradiha Area, Raniganj Coalfield", by Anoop Kumar Mukherjee *et al.*

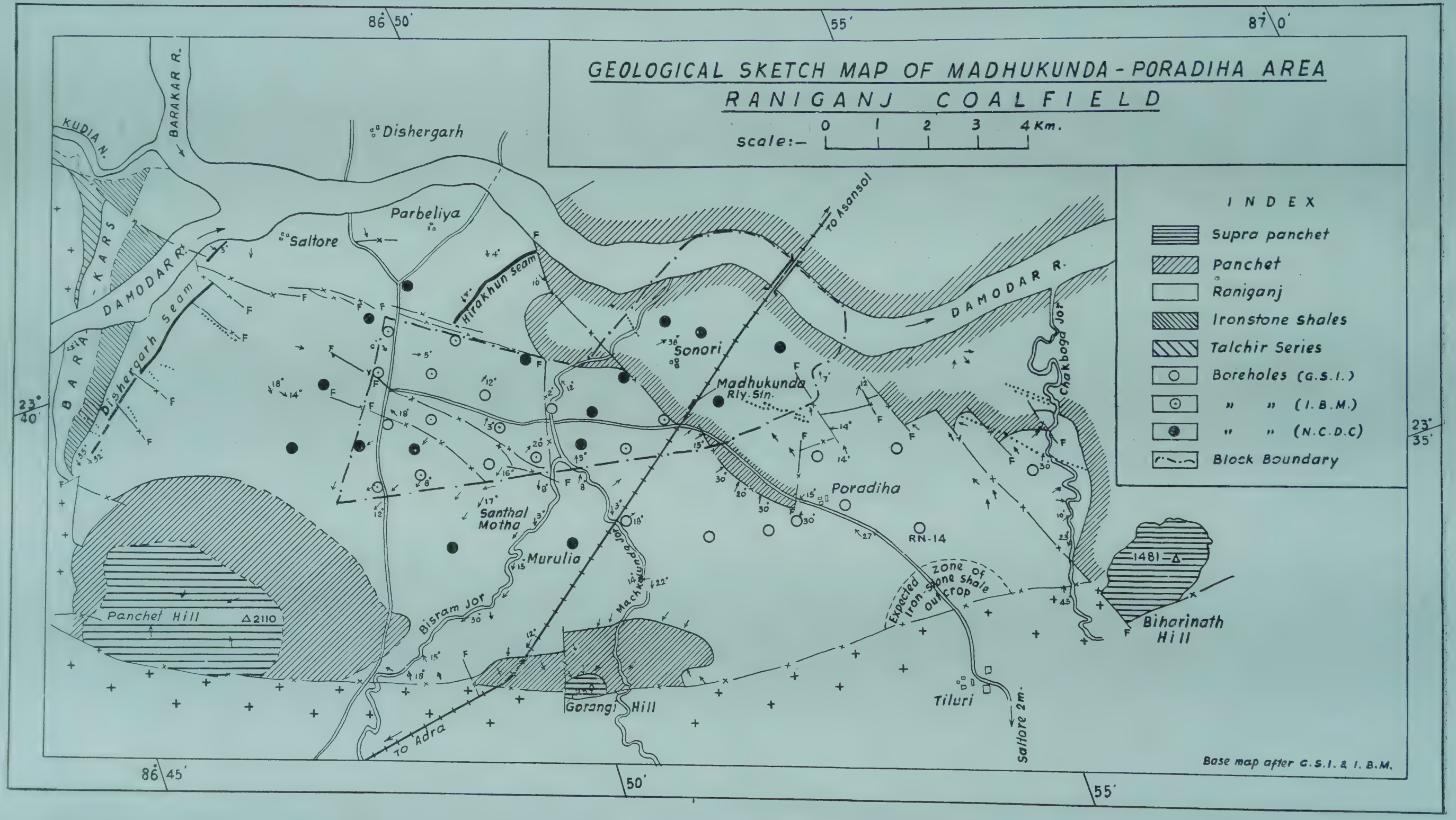


PLATE 1 — GEOLOGICAL SKETCH MAP OF MADHUKUNDA-PORADIHA AREA (RANIGANJ COALFIELD)

TABLE 1 — PROPERTIES OF THE COAL SEAMS IN THE MADHUKUNDA-PORADIHA AREA, RANIGANJ COALFIELD

Particulars	Hirakhun seam (R-X)		Gopalpur seam (R-IX)		Hizuli seam (R-VIII)		Burradhemo seam (R-V)		Dishergarh seam (R-IV)	
Thickness (in metres)	1·20-3·00		0·60-1·80		0·70-3·10		0·70-1·80		1·10-4·95	
	West	*East*	*West*	*East*	*West*	*East*	*West*	*East*	*West*	*East*
Moisture %	3·4-5·8	4·7*	2·7-5·4	4·1-6·0	2·6-5·2	3·7-5·5	1·8-3·5	3·9-5·5	1·5-2·9	2·1-5·2
Ash %	20·7-25·6	32·2	20·6-30·2	26·9-34·6	23·6-30·3	24·5-37·2	16·0-30·6	23·7-37·4	13·9-20·1	16·5-27·6
V.M. %	39·2	—	41·0-43·7	37·5-43·7	40·3-42·6	39·2-41·1	39·3-42·9	39·2-41·1	40·5-44·2	40·2-41·7
Carbon %	82·9	—	81·1-82·5	81·4	82·0-83·8	80·9-81·2	82·3-85·7	84·5	83·3-85·5	82·1-83·6
Hydrogen %	5·4	—	5·3-5·5	5·3	5·3-5·6	5·2-5·6	5·4-5·8	5·3	5·4-5·8	5·2-5·6
CV (kcal/kg)	8145	—	8025-8210	7980-8125	8080-8280	7940-8070	8175-8465	7940-8070	8290-8535	8060-8385
Caking index	<4	—	<4-7	<4	<4-10	<4-5	8-19	<4	14-23	<4-9
GK coke type	A	—	A-A$^+$	A	A-B	A	B$^+$-F	A	D-F	A$^+$-C

Note — (i) Figures for moisture and ash are at 60% RH and 40°C; for carbon, VM, hydrogen and CV on unit coal basis.
(ii) *West* — Western sector (Madhukunda area); *East* — Eastern sector (Poradiha area). *Analysis on as received basis.

However, the coals of the western sector (Madhukunda area) exhibit much brighter picture in so far its caking propensity, rank characteristics and potentiality are concerned. The area further to the east and south appears to be less promising. The gross reserve in the proved area (notified Madhukunda Block) is around 84 million tonnes for the Dishergarh (R-IV), Burradhemo (R-V), and Hizuli (R-VII) seams but this figure will increase when the entire area is taken into consideration.

Fine Chemicals Based on Toluene

Toluene is a major constituent of coke oven benzole and petroleum naphtha. About 0·85-1 per cent by weight of the coal carbonized in coke ovens usually appears in the form of crude benzole, of which toluene constitutes about 20 per cent. The total quantity of toluene obtainable from the five major steel plants, viz. Bhilai, Rourkela, Jamshedpur, Durgapur, Burnpur and the merchant coke ovens carbonizing approximately 10 million tonnes of coal per annum, works out to about 4 million gallons per annum. The Neyveli Lignite Project constitutes another potential source of toluene. Large amount of toluene are also available from petroleum refineries.

The total quantity of toluene recoverable from all existing sources may be about 35,000 tonnes annually. Although the production of explosives still takes up a fair quantity of toluene, new outlets will have to be found for the utilization of the large surplus.

Processes have been developed* at the Central Fuel Research Institute for the profitable utilization of coke oven benzole and petroleum stock toluene for the production of a wide variety of fine chemicals and intermediates that are currently being imported, such as benzaldehyde, benzoic acid, cinnamaldehyde, benzyl alcohol, caprolactam, cyclohexylamine, dicyclohexylamine, cresols, benzene, ortho-, meta- and para-xylens and synthetic sugar substitutes.

Benzaldehyde

Benzaldehyde is widely used as a flavouring agent in the beverages, food and perfumery industries. It also finds application as an ingredient in pharmaceuticals and as an intermediate in the synthesis of fine

*Based on a paper "Process and Project for the Production of Fine Chemicals based on Coke Oven and Petroleum Stock Toluene", by R. N. Bhattacharjee, Subodh K. Roy, H. S. Rao & A. Lahiri.

chemicals, viz. cinnamaldehyde, cinnamic acid, benzyl alcohol, etc.

In contrast to the earlier commercial processes for the manufacture of benzaldehyde through chlorination of toluene followed by hydrolysis with caustic soda, the CFRI process employs catalytic vapour phase aerial oxidation of toluene (*Indian Patent* No. 107124) and has the following advantages:

(i) The operation is simple, straightforward and continuous; (ii) air is used as the oxidizing agent; (iii) the product obtained is pure and free from chlorine; (iv) handling hazards (e.g. chlorine and caustic soda) are non-existent.

The yield of benzaldehyde by this process is about 70 per cent.

The total financial outlay for the project has been estimated to be around Rs. 5,40,000 for a plant capable of producing 150 tonnes of benzaldehyde per annum. The total profit from such a project is estimated to be as high as Rs 9,00,000 per annum, the cost of production being Rs 3·50 per kg.

Commercial development contract for this process has been given to Chemical & Metallurgical Design Company (P) Ltd., New Delhi, who will undertake design and engineering of the plants and supply turn key plants to enterpreneurs.

Benzoic Acid

Benzoic acid is in considerable demand in the food preservation, medicinal, plastic, dyestuffs and other industries. Benzoic acid and sodium benzoate are preservatives *par* excellence, especially for acidic foodstuffs with a high moisture content such as fruit juices, syrups, jams, jellies, etc.

The existing methods for the manufacture of benzoic acid from toluene have one or the other following drawbacks: (i) poor yield, (ii) discontinuous operation, or (iii) contamination of the product with undesirable ingredients.

CFRI process for the production of the chemical adopts catalytic vapour phase aerial oxidation of toluene (*Indian Patent* No. 107860) and yields 104 and 75 kg of benzoic acid per 100 kg of toluene charged using oxygen-enriched air and ordinary air respectively.

The benzoic acid obtained is pure and satisfies the required properties for consumption in the pharmaceutical, fine chemicals and food processing industries.

The total financial outlay for the project with a production capacity of 150 tonnes per annum has been estimated to be around Rs 5 lakhs. Gross profits per annum from such a project has been estimated to be about Rs 5 lakhs, the cost of production of benzoic acid per kg being Rs 3·20 (approx.).

This process has also been given to Chemical & Metallurgical Design Co. (P) Ltd., New Delhi, for commercial development.

Benzene and Xylenes

Benzene is used for the synthesis of *m*-aminophenol from which the tuberculostat PAS is manufactured. Ortho-xylene is used as a starting material for the manufacture of phthalic anhydride which finds extensive use in the resins and dyestuffs industry. Para-xylene is an intermediate in the manufacture of terephthalic acid required for the production of polyester. Oxidation of metaxylene yields isophthalic acid which finds application in the synthetic resin industry.

A good amount of benzene and xylenes are imported to meet the demands of the above industries to check drainage of valuable foreign exchange on this account. CFRI investigated for developing suitable process for their production from indigenous materials and developed a method for the same.

The process uses the technique of catalytic vapour phase disproportionation of toluene to benzene and a mixture of xylene isomers (*Indian Patent* No. 110604). The yields for benzene, ortho- and para-xylenes are 40, 10 and 10 per cent respectively.

The total financial outlay for the project is estimated to be around Rs 8 lakhs for a plant having an annual production target of 600 tonnes. The catalyst is prepared from indigenously available materials and is estimated to cost about Rs 5/- per kg. The cost of production of benzene and xylenes worked out to Rs. 2/- per kg approximately.

Benzonitrile

Benzonitrile can be used as a starting material for the manufacture of benzoic acid, benzaldehyde, triphenyl triazine, etc.

According to CFRI process, benzonitrile is produced from toluene in a single step through catalytic vapour phase ammoxidation

(aerial oxidation in presence of ammonia) technique. A yield of 60 per cent of benzonitrile is obtained.

Phenol

Phenol finds extensive use in pharmaceutical, resin, plastic and a host of other industries.

CFRI process for the manufacture of phenol is based on the two-stage liquid phase oxidation of toluene. In the first stage, toluene is catalytically oxidized to benzoic acid with air. In the second stage, benzoic acid is oxidized to phenol with air and steam. Seventy to eighty per cent of benzoic acid is converted to phenol whose yield comes to about 90 per cent.

Other chemicals and intermediates such as cinnamaldehyde, benzyl alcohol, caprolactam, cyclohexyl amine, dicyclohexylamine, cresols and synthetic sugar substitute can be prepared from one or the other material amongst benzaldehyde, benzoic acid, phenol or toluene by well-known chemical reactions. The studies have so far been limited to examine the feasibility. Further development work can be taken up if sponsored.

CFRI Recommends Remedy for Boiler Deposits

Experiencing troubles due to the formation of deposits in their boiler furnace, M/s. Daurala Sugar Works, Meerut, approached the Director, CFRI, to investigate into the causes of such formation and suggested possible measures of overcoming the trouble arising thereof. A team of CFRI scientists went to Meerut to conduct an inplant investigation of the boilers. Furnaces were studied under normal operating condition. Special emphasis was laid on the nature of combustion taking place inside the furnace and the nature of the inorganic constituents present in furnace deposits, refuses and the feed bagasse. Necessary samples were collected for conducting further studies at CFRI.

After completion of the investigation CFRI recommended the following measures towards alleviating the troubles: (i) The rate of bagasse firing as well as the depth of fuel bed in grate should be reduced to about three quarter of the existing levels. Combustion should be carried out with 20-25 per cent of excess air. (ii) All leaks in the boiler plants and in particular those occurring in the fuel gas duct connecting post-combustion chamber to chimney should be repaired to ensure proper operation of furnace. (iii) The plant should be adequately instrumented for not only obviating the deposit troubles but also for ensuring efficient operation of the plant. A detailed probe into the anomalies referred with regard to compositions of flue gases and temperatures prevailing in the post-combustion chamber should be taken up. (iv) A gas exhauster may be placed at the base of the chimney to ensure proper supply of combustion air and evacuation of dust-laden flue gas from furnace. (v) Trials with pretreatment of fuel with 1-1·5 per cent of kaolin may be tried in one of the furnaces.

These suggestions are not as such final answers to the problems, but rather broad indications on which further investigational work should be undertaken for seeking a permanent solution.

Notes & News

Indian Scientists' Delegation Visits USSR

A five-member Indian Scientists' Delegation led by Dr A. Lahiri, Director, Central Fuel Research Institute, Dhanbad, left for Moscow on 26 April 1970 for a four-week tour. The Scientists, representing different disciplines like fuels, metallurgy, mechanical engineering, toxicology and road engineering were the Directors of five different National Laboratories of the Council of Scientific & Industrial Research. The tour was sponsored under Indo-Soviet Cultural & Scientific Exchange Programme (1969-70).

During their stay in Soviet Union, members of the delegation visited research laboratories, academic institutions and industrial centres to acquaint themselves with modern trends in research and development activities in their respective disciplines.

Later, Dr Lahiri visited Canada to participate in the Conference on "Energy Fuels — New Developments in Fuel Technology" from 31 May to 3 June 1970 at Ottawa and in a Meeting of the Institute of Fuel Commonwealth Liaison Group, following the Conference.

During Dr Lahiri's absence, Dr N. G. Basak, Deputy Director, discharged the duties of the Director as Deputy Director-in-Charge.

Committees and Meetings

The Thirteenth Meeting of the Executive Council of the Central Fuel Research Institute was held at the CFRI, Dhanbad, on the 14 April 1970 with Sir Jehangir Ghandy, Director, Tata Sons (P) Ltd., in the Chair. A brief resume of the important items considered by the Executive Council is presented below.

Scrutinizing the programme of work for 1970-71 and the Annual Report for 1969-70, the Council expressed its satisfaction finding that most of the programmes were related to important industrial and national problems. Regarding securing sponsors for the research projects, Dr Lahiri, Director, CFRI, pointed out that the industry could not be expected to be involved in such ventures until a point was reached when a feasibility study could be made to assess chances of commercial success. For attaining the stage, that is till commercial feasibility study is possible, Dr Lahiri opined that the initial investment had to be made by the laboratories. He apprised the Council that CFRI had adopted a new line of approach in this respect. Agreements were made with consultants to whom CFRI would supply necessary technical data on CFRI processes so that the consultants would act as development contractors for the processes and would be in a position to supply turn-key plants with financial guarantee to any entrepreneur. Dr Lahiri apprised the Council that such steps had already paid dividends and four CFRI processes (production of benzoic acid, benzaldehyde, 3- and 4-cyanopyridines) were being commercialized through M/s Chemical & Metallurgical Design Co., a consulting engineering firm of New Delhi. With regard to CFRI processes relating to production of xylenes, anthraquinone, pneumatic separator, oleoflotation, etc., negotiations are being carried out with reputed firms in the field of consultancy and engineering.

Dr Lahiri further informed the Council of CFRI's endeavour in seeking help of NCDC for putting up of large scale demonstration plants such as for production of formed coke. NCDC had appointed consulting engineers to assess the technical feasibility of the process. Dr Lahiri also stated that CFRI had prepared a feasibility report on a 9-crore domestic fuel project to be located in Madhya Pradesh and the project was under study of NCDC and the Govt. of Madhya Pradesh. A similar project was also undertaken for a private firm in Raniganj. The Council was also made aware of CFRI's collaboration with a consultant firm for a developmental project of Govt. of Orissa and the Deptt. of Mines & Metals for the production of pig iron utilizing formed coke based on CFRI process.

In respect of another CFRI process (pneumatic separation) for commercialization, Dr Lahiri said that discussions were being held with prospective manufacturers and especially with M/s Tata Robinson Frasers and it was hoped that a trial order would be secured in some industrial establishment to step up the scale of operation from 5 ton an hour at CFRI to 25-50 ton an hour in an industrial plant. Without this development stage and trial order, the manufacturers could not be expected to develop the equipment to a commercial stage for general acceptance. It was expected that HSL and TISCO would be interested in these projects. He further stated that 'Oleoflotation' process which was successfully demonstrated on a quarter ton an hour pilot plant at CFRI is being negotiated for development with M/s McNally Bird Engineering Co. Ltd. They would also have to find a customer for developing the first prototype for trials. Dr Lahiri stated that both NCDC and HSL would benefit and may promote this venture and set up a unit in one of their existing washeries.

About projects on conversion of coal to oil and fluid bed combustion of low grade coal, Dr Lahiri stated that the projects were of national importance and required support from appropriate governmental organizations. With regard to fluid bed combustion, Dr Lahiri expressed that the Coal Board could sponsor the work in the interest of conservation of good quality coal and utilization of inferior coals. For development, funds from other sources might be necessary. Participation of commercial firms might be also considered for design, fabrication, etc., at appropriate stage. The Council stressed the importance of these projects and recommended that the work by the CFRI be fully supported.

Regarding funds, the Council strongly recommended that as far as the CFRI was concerned the minimum demands should be met,

and considered that CSIR may redistribute Fourth Plan allocation in the light of national priorities and meet the requirements of CFRI Projects in full. The Council also recommended that in case of shortfalls, the earnings of the Laboratory may be earmarked for reinvestment for its developmental projects, which may cover at least 50 per cent of the shortfall.

While considering the pilot plant project for coal hydrogenation and feasibility report by Dr E. E. Donath, US Expert, the Council noted with satisfaction that the USAID has more or less endorsed the findings of the CFRI. As regards possibilities of exploiting Assam coal, the Council noted that the expert felt that setting up of the liquid phase hydrogenation equipment of 18-20 kg/hr was an essential step for further work and for any detailed feasibility study or for setting up of a demonstration plant. The Council, therefore, reiterated its earlier decision that priority be given to this project and that funds and foreign exchange necessary may be made available forthwith.

The Council noted that some of the equipments were already on order through the US non-project loan and urged the CSIR to secure the remaining foreign exchange requirements either through USAID non-project loan or UNTAM as may be convenient.

The Council approved of the proposal for installation of a multi-purpose fluid bed oxidation unit and endorsed the view of the Director that scale-up studies of the order envisaged is an important step for commercialization of the process and urged the allotment of the supporting funds by NRDC. The Council also agreed that development of such a process should be carried out in an industrial organization and possibly in collaboration.

The Council approved of the proposals for collaborative research with NAPCA (USA) and recommended that the CSIR may support the proposal of the following schemes for financing under PL-480: (i) Sulphur in coal: problem of sulphur dioxide pollution, potential for sulphur recovery; (ii) oleo-flotation; (iii) electrostatic precipitation; and (iv) coal beneficiation.

The members also felt that CFRI should also collaborate with power generation authorities in India in the study of corrosion and erosion problems of power plant boilers. To this Dr Lahiri said that the Institute was maintaining a close liaison with power plant authorities and proposed to set up powdered fuel fired rigs for studying corrosion and erosion problems. For inplant studies Dr Lahiri suggested a collaborative effort between CFRI and power plant authorities, and requested the Chairman, Coal Board, to urge these authorities to embark on such collaborative ventures in the interest of utilization of low grade coals.

The Council discussed the proposal of renewal of grant-in-aid for the CB and CR scheme but reserved its decision till its technical Committee submitted recommendations. It suggested that CFRI should work out proposals for large scale coking tests in consultation with CEDB and Bokaro Steel Plant authorities in view of the decision of Ministry of Steel to have commercial scale testing facilities at Bokaro Steel Plant and other steel plants in due course.

The Council also approved of the purchase of a high temperature graphite furnace in view of the special nature of the equipment and because the facilities available at CGCRI were not adequate.

The Council approved the proposal for publication of (i) Proceedings of the Symposium on Chemicals and Oil from Coal, and (ii) Monographs on Coal Carbonization, Coal Preparation and Dishergarh Seam.

■ Studies at the Coal Survey Laboratory, Raniganj, have indicated the occurrence of Grade II coal in 3 principal coal seams in Mejhia area, south of the Damodar in the District of Bankura. Their quality suggests their suitability for power station. This was announced at the Coal Survey Advisory Committee Meeting for Coal Survey Laboratory (CFRI), Raniganj, held at Sanctoria on 4 April 1970 under the Chairmanship of Mr Ll. D. Hughes. This finding indicated the existence of coal resources in a region which was so far not considered as a coal source.

Further study in the north eastern part of Raniganj coalfield has revealed that the important Samla seam possibly remains virgin in the large tract below the working seams and retaining its quality as observed in working mines. This is proved to have also extended beyond the working areas enhancing the reserve position of the good quality Samla seam. It was stated that to the further east of Madhaipur dip fault there was no previous information about the existence of any Samla seam outcrop till the recent finding of the CSL, whereby the outcrop of Samla seam had been proved in Pansuli area in a newly exposed quarry. It was pointed out that most of the working collieries in Samla sector east of Pandaveswar Rly Station were working the 5th horizon and not R-IV or Samla seam as was thought earlier and the major part of the Samla seam was possibly lying virgin. This was corroborated by the GSI representative on the basis of their drilling data in the eastern Raniganj coalfield.

The Committee was also informed of the existence of high moisture and inferior grade coals of the Barakar measures in the western Bank of the Ajoy river.

The work of the Survey Laboratory during the year has also confirmed the earlier projection of laboratory that the coals of Kalimati, Brindabanpur, Gopinathpur and Salanpur seams are of limited use as coking blends in view of their poorer coking property. They, in view of their large reserve, however, have great potentialities for use in power generation in super power station being erected in the Maithon and Panchet area.

While discussing the question of spontaneous combustion of coal stacks, Shri A. K. Moitra, CFRI, elaborated on the principles underlying measures adopted for their prevention. In this connection it was pointed out by the representative of the West Bengal Electricity Board that regular bulldozing of slack coal stacks appeared to have prevented spontaneous combustion at Bandel Thermal Power Station.

Noting with interest the occurrence of caking and non-caking coals in various virgin tracts, viz. Poradiha, Churulia and Eastern extension of the Raniganj coalfield in addition to earlier findings, the Committee chalked out the future programme of quality assessment.

The Coal Survey Laboratory, Raniganj, has been continuing Physical and Chemical Survey in selected tracts, viz. Nirsa-Mugma area, Salanpur area, and a few other coal bearing regions of the field in close collaboration with Geological Survey of India for finding out their suitability in various Industries.

■ In the Forty-Sixth Annual General Meeting of the Indian Mine Managers' Association held at Central Fuel Research Institute, Dhanbad, on the 18 April 1970 under the Presidentship of Mr R. N. Sharma, Chief Mining Engineer,

TISCO Collieries, Mr Sharma, besides dealing with employment, education and training of Mining Engineers as well as the law and order situation in the collieries, focused attention on the problems of coking coal. He expressed the concern of the planning authorities of the country regarding quick exhaustion of coking coal reserves. As measures of economy in the use of prime coking coal, he pointed out that efforts were constantly being launched to utilize non-coking coals in the coking blends and as such for metallurgical purposes. To lengthen the life of coking coal reserves, Mr Sharma urged that the Association should pay more attention towards achieving greater percentage extraction. He also mentioned the difficulties of the authorities of small holdings towards larger investment necessitated by difficult mining conditions and changes in layouts of old holdings. Mr Sharma, therefore, stressed on recasting the present holdings into much larger units and urged the mine owners to opt for voluntary amalgamation instead of compulsory amalgamation that may have to be enforced by the Government.

As a new approach, Mr Sharma suggested assigning of such holdings to different steel plants for development, financing and despatch of coal on a cooperative basis with the present mine managements. The left-over blocks, he opined, should be kept earmarked for meeting the requirements of the future expansion of the steel industry. Mr Sharma referring to Government's decision for the formation of a technical guild to assist it in the reorganization programme of mines felt that the responsibility of ultimate planning and reconstruction should be left to the management.

Speaking of the technique of sub-level caving *vis-à-vis* the sand stowing, Mr Sharma proposed that construction of housing estates should be stopped immediately by regulation and old estates removed to non-coal-bearing areas to enable large scale application of the sub-level caving method. Unless this was done, he pointed out, production would be seriously hampered.

Mr Sharma recommended creation of Cooperative Research Centres under the Producers' Association for more R & D activities for the use of mining industry.

Coal Liquids Yield Carbon Black Feedstock

Ashland Oil & Refining Co. has announced a process for making carbon black feedstock from the tar produced by low-temperature carbonization (LTC) of coal.

FMC's Char Oil Energy Development (COED) process uses multiplestage fluidized-bed pyrolysis with increasing stage temperatures to drive off volatile matter at controlled rates and temperatures. It converts a high percentage of the coal to gas and condensable oil products. So far the tarry liquid has not been competitive with crude oil. Research workers have tried many techniques to upgrade this LTC tar, and have produced a variety of useful products, but their processes have been too complex to be economically feasible.

Ashland chemical engineers have now developed procedures to convert LTC tar into carbon black feedstock. The procedures are not only technically practicable, but potentially profitable as well.

In the Ashland process, the tar is first heated and blended with benzene to reduce viscosity, centrifuged to remove solids, and then azeotropically distilled to remove water. Next, the dry, solids-free tar is subjected to fixed-bed catalytic hydrotreatment to remove hetero atoms-oxygen, nitrogen and sulphur which would otherwise reduce the yield of carbon black. The hydrotreated tar is then fractionated at 600°F. to produce an overhead cut and a bottoms fraction.

The bottoms fraction can be used as carbon black feedstock without further processing. It produces a satisfactory grade of carbon black, but the yield is only about 80 per cent of that of the standard petroleum feedstock, apparently because of incomplete removal of hetero atoms. To achieve the process goal — a bottoms material with 90 per cent by weight carbon content, the Ashland engineers give this fraction a second hydrotreatment.

According to Ashland's United Carbon division, performance of this second-pass tar in a pilot-scale carbon black reactor is practically identical to that of the standard feedstock.

Also, rubber samples compounded with the LTC carbon black are substantially the same, in elasticity modulus, tensile strength, and abrasion resistance, as those made with carbon black from standard feedstock. [*Chemical & Engineering News*, September 29, 1969].

New Coal Combustion System

More efficient burning and faster release of heat from coal are promised by a new type of combustor now being tested by Australian mineral chemists. A small, fluidized bed combustor has been designed in which heat from the coal is transferred to water circulating in a metal coil buried in the bed. In addition to high heat release and heat transfer rates, the new system does not have the liability to fouling and corrosion heat exchange surfaces of conventionally fired furnaces.

A bed containing a mass of fine particles of a solid material such as coal can be fluidized by an upward current of gas. The particles are jostled and tossed about by the gas stream and the mixing leads to greater efficiency in heat transfer. But the full benefits of fluidization can be gained only if provision is made to transfer the heat generated from the bed efficiently. Thus, the new system combined the processes of heat release and heat transfer by immersing a copper, water-heating coil in the bed.

A maximum rate of heat transfer of about 124,000 British thermal units an hour to the cubic foot of combustion chamber was achieved. Conventionally fired furnaces produce 5,000 to 40,000. Besides this substantial gain, it proved possible to procure complete combustion with less than 2 per cent excess air compared with about 10 times that quantity required by ordinary boiler furances.

It has proved possible to maintain stable combustion at temperatures as low as 460°C, even with low rank coal. The rate of transfer of heat to the buried coil was several times greater than that achieved when a coil was located above the bed. The combustor operated smoothly throughout the experiments and there was no evidence of either clinker formation on the water coil, or abrasion of metal surfaces by the sand used to maintain a continuous flow of bed material through the overflow pipe.

The heat transfer process in the fluidized bed combustion system was simulated and appropriate equations were solved by an analogue computer. The results suggest that the highest rates of heat transfer are obtained when the hot particles have short residence times, and give most of their heat to the water coil in intervals as short as thousandths of a second.

Combustion studies under fluid bed operation were also undertaken at CFRI, Dhanbad. Experiments with different sizes of coal, ash and sand carried out in 80 mm. dia. column revealed that for coal ash particles of 1·6 to 0 mm. size

and their mixtures containing 5-10 per cent coal, the minimum fluidization velocity for good mixing was around 0·4 m./sec., while that for 3·2 to 0 mm. size, it was about 0·6 m./sec. The corresponding velocities for fire brick and sand particles were higher being about 0·7 m./sec. for 1·6 mm.—0 particles and 1 m./sec. for 3·2 mm.—0 particles.

The elutriation loss in these tests varied between 8 and 15 per cent, wider size range of feed giving higher elutriation losses.

Following the above work, the fabrication and installation of a 10 kg. per hour fluid bed combustor with ancilliary equipment were completed.

Preventing Boiler Corrosion

Test recentiy conducted at a Scottish power station proved that a blanket of plastic balls, floating on the water surface in a machine hot well, provides a cheap, effective and simple means of reducing corrosion in boilers and condensate systems by limiting the oxygen absorbed by the water during shutdown periods.

The trials took place at Braehead power station, Renfrew, where the problem of dissolved oxygen in recirculated condensate required special attention because the station shuts down for about six hours each night. During that period, as the temperature in the machine hot wells drops, the oxygen content in the water increases so that, by morning runup time, oxygen content reaches levels which would have serious corrosive effects in boilers and condensate systems, with the resulting penalty of far greater maintenance costs and downtime of plant.

It was decided, therefore, to try maintaining hot well water temperature by the Allplas system in which hollow plastic balls float on the surface to form an insulating blanket. One machine hot well was therefore covered with 13,500 Allplas balls of 45 mm. diameter, made of polypropylene.

The capital cost of introducing the Allplas blanket system is low and there are no installation or maintenance costs. Personnel at Braehead responsible for the experiment are satisfied with the results obtained and have arranged to apply Allplas balls to the other machine hot wells.

The technique is already widely used by industry to reduce heat losses from heated open process tanks and for suppressing surface fumes, retarding the onset of freezing and preventing the splashing of corrosive liquids. The Braehead trials indicate that the ball blanket also offers a cheap, self-operating and simple solution to oxygen corrosion problems in boiler houses and steam raising plant in general. [*Energy International*, (1969) **6**, 2, 34].

Feher Cycle Engine

An engine 25 per cent more efficient than existing gas or steam turbines is under development at the McDonnell Douglas Corp's laboratory at Newport Beach, California, USA.

The engine uses chemical, solar or nuclear energy as a heat source. Advantages of the cycle are achieved by operating entirely above the critical pressure of the working fluid (carbon dioxide). This is liquefied at one point in the closed cycle, allowing the use of a pump instead of a compressor and the use of a recuperator to recover a large portion of the turbine exhaust heat.

Because the engine is compact, it has a high power to volume ratio. Its simplicity results in reliability, and its thermal efficiency exceeds 50 per cent, the company reports. Instead of the 30 stages required in steam turbines, only two are needed to produce the same amount of power in the Feher cycle.

Potential applications include electricity generation for large metropolitan areas or for space stations and use in portable electric generators for military use. [*Energy International*, (1969) **6**, 2, 34].

Electricity from Earth's Steam

Engineers in the United States have begun an active programme of prospecting for new sources of geothermal energy —an electricity source which may some day rival conventional and even nuclear power.

Geothermal ' belts' exist in many parts of the world. In these areas, molten rock (magma) lies relatively near the surface and heats water contained in permeable rock above. This heated water, becoming steam, may escape to the surface through fissures, and the fissures can be tapped by wells and the steam conveyed to the turbines of power plants.

In general, the heat of the earth increases with depth; it is about 492 degrees F (260 degrees C) at 9843 feet (3000 metres) and about 1183 degrees F (650 degrees C) at 19,685 feet (6000 metres).

Geothermal drilling started in the Big Geysers area north of San Francisco more than 40 years ago but engineers were discouraged by the small demand for the steam and by the rather primitive state of geothermal technology. New drilling began in 1956 and was more successful. Drilling for steam can produce unexpected and spectacular results. Unless well holes are quickly capped, they may blow out of control. One early well blew out and sent steam and thousands of tons of earth into the air. It proved impossible to cap and is still blowing today.

By 1960 the Pacific Gas and Electric Company was using some geothermal steam in its plants. Studies showed that the cost of this power was almost exactly the same as that produced in a conventional steam power plant.

Another important geothermal area is the Salton Sea, south of Los Angles, a hot water field. Developers have had difficulty in screening out heavy concentrations of minerals in the water and operations have been reduced pending the development of improved processes.

The first geothermal plant was built in northern Italy in 1904. Although it was destroyed in World War II, it was rebuilt and is still functioning. For some 50 years the Italian plant was the only one of its kind in the world.

In New Zealand two American experts made a study of one field and estimated that it contains enough high pressure steam to last about 1000 years.

The next big step in geothermal technology may be the drilling of deeper wells which increase the electric power output per well. Engineers are now working on improved deep-drilling techniques. Another approach would be to explode nuclear devices at great depths to create vast reservoirs into which water could be injected and recirculated to produce steam as well as minerals. Engineers believe this would make geothermal energy competitive with nuclear power.

Two advantages of geothermal power are that there is no air pollution as in coal-burning power plants, and there is no radioactive waste problem as in nuclear plants. [*The American Reporter*, (1970) xx, 1, Jan. 14, 9].

US Aided Power Projects in India

India's power generating capacity touched the 16 million kilowatts

mark as of 1969, seven times as large as the capacity in 1950. Of this total, over one-third is generated by the 30 power projects aided by the United States. Twenty of the projects have an installed generating capacity of 4 million kilowatts and the other ten 2·5 million kilowatts, making a total of 6·5 million kilowatts. Details of the contributions of a select few of them to the industrialization and development of the areas where they are situated are briefly given.

Dhuvaran

Dhuvaran, 5,34,000 kilowatts, is providing power for both industrial and agricultural development in Gujarat. The State has a high potential for industrialization. Petroleum-refining and petrochemical industries are developing rapidly as a result of discoveries of oil and gas in the State. Dhuvaran power has helped the electrification of 4000 additional villages in Gujarat. It is also providing electricity for 1,00,000 irrigation wells. It will be linked by a grid with the Tarapur atomic power project and other plants in both Gujarat and Maharashtra, for wider utilization.

Chandrapura

The 4,20,000-kilowatt Chandrapura thermal power station in Bihar is the largest of its type in India. Power produced at the plant is making a significant impact on industrial production in Bihar and West Bengal. A number of new industries have started production in these States, and many existing plants have expanded output. Several coal mines have been mechanized. In addition, rural electrification has made big strides. In the field of rail transport, Chandrapura power has helped to extend electrification of the 600-mile track from Calcutta to Mughalsarai. Fast electric locomotives now pull goods trains carrying coal, steel and iron ore — contrasting sharply with the situation a few years back when steam locomotives were hard put to move the traffic load.

Bandel

The Bandel thermal power station (capacity: 3,55,600 kilowatts) is located in West Bengal. Bandel power has made possible the establishment or expansion of chemical and heavy and light manufacturing industries creating jobs for many thousands in the State. Power is also being supplied to a large number of irrigation pump-sets, helping to increase West Bengal's agricultural production.

Indraprastha

The Indraprastha (Delhi 'C') station is developing into north-west India's largest thermal power plant. Its 2,24,000 kilowatts power production has improved the capital's power supply perceptibly. Many of the growing industries around Delhi which were unable to operate at full capacity have increased their output. Agriculture too has benefited through wider electrification and the energizing of pump-sets on the farms of Delhi and Haryana.

Sabarigiri

The 3,00,000 kilowatt Sabarigiri hydroelectric project has more than doubled the installed power-generating capacity of Kerala. Named after Kerala's holy mountain — Sabarigiri, the project harnesses the enormous power potential of two of India's shortest rivers. The project includes a dam across the River Pamba and two dams on the River Kakki, plus a network of tunnels and penstock pipes. Sabarigiri is already helping to expand many existing industries or establish new ones. These industries include aluminium, bicycles, cement, chemicals, fertilizers, firebricks, glassware, nylon, plywood, rayon, rubber, sawmilling, sewing-machines, soap, textiles, tyres and vanaspati. In addition, a large-scale expansion of irrigation from wells, using electric pump-sets operated by Sabarigiri power, is helping Kerala farmers bring more land under rice.

Sharavathi

The Sharabathi hydroelectric power project in Mysore State is planned to be developed into one of the largest power projects in the world. Its present target capacity is 7,12,800 kilowatts, but the ultimate potential exceeds one million kilowatts.

The project has greatly benefited the economy of Mysore State, whose industries include aircraft, aluminium, cement, chemicals, electronics, engineering, machine tools, paper, telephones and textiles.

Farmers are being encouraged to install electric pump-sets for irrigation, making possible two and sometimes three crops a year.

The Mysore Government is also supplying large amounts of Sharavathi power to Andhra Pradesh, Kerala and Tamil Nadu.

Satpura

One of the largest power plants in Central India, Satpura (3,12,300 kilowatts) has doubled the installed power capacity of Madhya Pradesh, a large area of which is being rapidly industrialized.

Among major industrial units being expanded or established in the State are cement, fertilizer, paper and textile factories. Satpura power is also being provided to neighbouring Rajasthan State.

Talcher

The commissioning of the Talcher thermal power station in February 1968 by Prime Minister Indira Gandhi marked a turning-point in Orissa's power supply situation.

The main source of power in northern Orissa previously was the Hirakud hydroelectric station, also assisted by the United States. The 2,50,000 kilowatts Talcher project has firmed up Hirakud's power and more than doubled the overall capacity of the northern Orissa grid.

Orissa is rich in mineral resources, and has mineral-based industries of recent growth such as aluminium, cement, glass, iron and steel.

Situated in a major coalfield Talcher has scope for enormous future expansion. [*The American Reporter*, (1970) xx, 1, Jan. 14, 8].

Symposium on Mines Mechanization

A symposium on Mine Mechanization was held at the Banaras Hindu University, Varanasi, on 13, 14 and 15 March 1970, under the auspices of the Department of Mining. On the occasion Shri K. S. R. Chari, Coal Mining Adviser to the Government of India, inaugurated the underground mine of the Department of Mining, which has been constructed with a special grant of Rs two lakhs from the University Grants Commission.

26 Papers were presented at the symposium spread over 5 technical sessions dealing with various aspects of mine mechanization. The proceedings of the symposium is available (at Rs 15/- inclusive of postage and Rs 10/- for students) from the Head, Department of Mining, Banaras Hindu University, Varanasi 5.

CFRI Participation in Exhibition

Central Fuel Research Institute participated in an exhibition held in connection with the 14th International Meet of the members

A VIEW OF THE CFRI PAVILION AT THE EXHIBITION

of the Lions' Club, at Kustore, Dhanbad, from 23 to 26 April 1970.

Due to limitation of space, CFRI displayed only models of Fischer-Tropsch Process for production of synthetic oil from coal, Phthalic Anhydride Plant for the production of the chemical (Phthalic Anhydride) from coal tar, Tar Hydrogenation Plant for the production of synthetic crude and Briquetting cum Curing Plant for the production of tailor-made metallurgical/domestic briquettes. Besides, specimen samples of products obtained, either as finished products from various CFRI pilot plants or commercial ones being produced by CFRI developed processes were exhibited.

The visitors were from different parts of India and the neighbouring eastern countries interested in the development through application of science and technology. They evinced great interest in the activities of the Institute in general and the details of the processes were explained to them. They were appreciative of the industry-oriented work of the Institute. Some of them later visited the Institute also.

Deputation

Dr P. N. Mukherjee, Assistant Director, resumed duties on 27 May 1970 after completion of a three-month advanced training in UK under an exchange programme between the CSIR and the British Council. The object of his visit was to get conversant with the modern trends of research in catalysis and surface chemistry.

Dr Mukherjee was associated with Prof. M. W. Roberts at the University of Bradford for two months and a half (26 Feb. to 7 May 1970). He had the opportunity to study the following sophisticated techniques:

1. Ultra high vacuum technique for studying adsorption on metals and oxides.
2. Electrical and catalytic properties of doped semiconductors.
3. Work function measurements to study the state of adsorbed molecules on gas-solid interface.
4. Application of mass spectrometry in catalysis.
5. Low-energy electron diffraction and AUGER spectroscopy to study the state of adsorbed species on surface.
6. Application of gas chromatography in reaction kinetics.
7. Application of ESR to study the state of adsorbed species on solid catalysts.

Dr Mukherjee had the opportunity to visit the Laboratories of Prof. Kemball, FRS, Edinburg, University; Dr F. A. Stone, Bristol University, Prof. Sykes, Queen Mary College, London University, Prof. R. M. Barrer, Imperial College of Science & Technology and Warren Spring Laboratory (Dr Dorling).

■ Mr S. Ghose, Scientist, resumed duties on the 4 May 1970 after his return from West Germany where he had been on deputation under German Academic Exchange Programme for studying the methods and techniques of latest research work in coal geology and coal petrology.

In West Germany Mr Ghose was associated with the following projects:

1. Rank variation of coal laterally as well as in depths, its causes and relation to the structural and geological history of the areas, like Ruhr Basin, Rhine Basin, Saar Basin, etc.

2. Seam maps — Iso-ash and Iso-vol.
3. Underground mapping and preparation of structural maps.
4. Carbon Isotope study in relation to gas emmission from coal.
5. Carbon Ratio Theory in and relation to prospecting of oil and gas.
6. Study of peat under microscope and its utilization.
7. Study of lignites and its briquetting in relation to its microscopic structures, etc.
8. Petrographic studies under reflected light of peat, lignite, bituminous coals and anthracite. Studies of the above under fluorescent light.
9. Measurement of reflectance of coal macerals by photomultiplier in conjunction with recorders and computers.
10. Prediction of carbonization properties of coking coal and coking blends from maceral and reflectance studies.
11. Isolation of individual macerals and study of their properties.

Mr Ghose visited well-known establishments like (1) Geologische Landesamt, Nordnhlin Westfalen, Krefeld; (2) Bergbau-Ferschung foreschungistitut des steinkohlen-bergbauvereins, Essen; (3) Bundes-anstalt Bondenferschung, Hannover; (4) Torf Institut, Hannover; (5) Institut fur Brennstoff-chemie, Aachen; (6) Institut fur Geolgische, Aachen, where he had the opportunity to work under and discuss with eminent scientists in the line.

■ Mr Satyagopal Tumuluri, Scientist, resumed duties on 2 May 1970 after completion of his deputation to UK for a period of three months under the programme of Exchange of Scientists between the CSIR and the British Council.

■ Shri Kunda Singh, Scientist 'B', was deputed to Poland on 31 May 1970 for training in briquetting and coal carbonization under the programme of exchange of scientists between CSIR and the Polish Academy of Sciences.

PROF. NAGENDRA JHA (*right*), BIHAR MINISTER FOR MINES, IS DISCUSSING WITH MR S. K. DASGUPTA, DEPUTY DIRECTOR, PILOT PLANTS

Honours and Awards

Mr B. K. Sinha, Scientist, has been elected a Fellow of the Statistical Society, London (UK).

Mr P. K. Bhattacharjya, SSA, has been elected an Associate of the Institute of Information Scientists, London.

Retirement

Our well wishes to Shri B. L. Patra, Senior Stenographer, who retired on 29-4-1970 (AN) for restful life.

Resignation

We wish success to the following of our colleagues who have resigned: (i) Dr S. S. Misra, Scientist, w.e.f. 6-4-1970 (AN); (ii) Dr K. K. Deb, Pool Officer, whose appointment as Pool Officer ended w.e.f. 27-4-1970 (AN); (iii) Shri A. B. Bandopadhyay, SSA, w.e.f. 1-5-1970 (AN).

Promotion

We congratulate Shri P. K. Sinha, Sr. Stenographer, on his promotion to the present rank w.e.f. 30-4-1970 (FN).

Visitors

Bihar Minister at CFRI — Prof. Nagendra Jha, Hon'ble Minister of Mines, Government of Bihar, paid a visit to CFRI on 22 May 1970. Prof. Jha was received and shown round the Institute by Shri S. K. Das Gupta, Deputy Director (Pilot Plants).

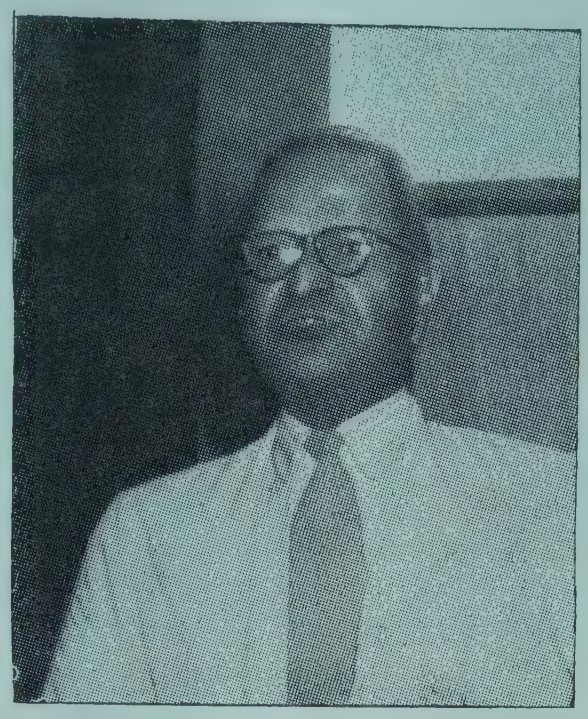
The Minister was much impressed by the largely industry-oriented research of the Institute and by the Institute's feasibility studies on the development of coal based industrial complexes. One such study was for the Bokaro-Ramgarh area, Bihar. The Minister was apprised of the efficient utilization pattern for lomex, a byproduct of Barauni Refinery, based on a study by the Institute. It is now being employed for carbon-black manufacture and as an industrial fuel.

OBITUARY

We record with deep regret the passing away of Dr M. S. Krishnan, an eminent scientist and a former Director of the Geological Survey of India.

A geologist of international repute, an able administrator and a teacher, Dr Krishnan had been one of the leaders in earth sciences. He was the first Indian to act as the Director of GSI, first in 1949 for few months and later in 1951 till he moved to Delhi.

Earlier, he was Director of the Indian Bureau of Mines for two years from November 1948. He was Mineral Adviser to the Union Ministry of Natural Resources and Scientific Research for about two years up to April 1957 when he was appointed Director of the Indian School of Mines & Applied Geology at Dhanbad. He voluntarily retired from Government service in August 1958. Shortly after, he joined the Geology & Geophysics Institute for some three years, teaching and training aspiring geologists and geophysicists. He was the first Director of the Central Board of Geophysics (now the National Geophysical Research Institute at Hyderabad), set up in 1961. His book "Geology of India and Burma" has been the standard text book for postgraduate and graduate classes in all Indian Universities for years and is the standard reference book in many universities abroad.



Dr M. S. Krishnan

Dr Krishnan was a member of the Coal Committee of the Government of India in 1937 in the pre-independence days. He was General President of the Indian Science Congress in 1956. For his services to the country, Dr Krishnan was awarded the title of Padma Bhushan.

Dr Krishnan was associated with CFRI since its inception. He delivered the Fourth Foundation Lecture of the Institute in 1953. The title of his lecture was "Some Problems in the Geology of the Gondwana Formation".

Editorial — *Contd from page* 70

of hydrocarbons from wax to ethylene. It can also produce other chemicals, industrial alcohols, detergents, synthetic fatty acids, etc. The high cost of oxygen and the conversion factors, viz. about 5 tonnes of coal being required for a tonne of liquid products, makes the process more suitable for production of chemicals than basic energy fuels.

The third way, viz. the Bergius process which involves direct contact of the coal substance with hydrogen in the presence of a catalyst under pressure, which removes the hetero-atoms (oxygen, nitrogen and sulphur and, at the same time, enriches the coal in hydrogen content, converting it in the process into a synthetic crude), is the route that is now receiving the greatest attention. Several plants based on the process were built in Germany and Japan.

At the CFRI, work in this field has been revived and major programmes for R & D outlined for exploring all the three routes, especially the third. The added interest in hydrogenation route comes from the existence of rather unique type of coal in Assam, which has been described as 'the world's most hydrogenable coal'. It is low in ash, high in hydrogen and its high sulphur content is an asset rather than a liability as it is in conventional use. The conversion ratios are of the order of 2:1 for coal to oil, if hydrogen could be produced from other sources such as from natural gas. The occurrence of petroleum, natural gas and coal in one area adds also to the possibility of process integration, which could be of commercial advantage. However, the Institute's interest is not merely confined to the coals of Assam. It has now been possible to develop a technique

(*Contd on page* 90)

CFRI ABSTRACTS*

PRODUCTION OF PHTHALIC ANHYDRIDE BY THE VAPOUR PHASE OXIDATION OF COAL TAR OILS, by C. S. B. Nair.

Investigations on fluid bed vapour phase oxidation of coal tar fractions for the production of phthalic anhydride showed that the CFRI catalyst was quite active and retained its activity over long periods. The attrition loss of the catalyst over a 200 hr period of actual operation was not appreciable and indicated that the time for overall replacement of the catalyst was about 3 years. Crude naphthalene cake (88 per cent naphthalene) gave phthalic anhydride yields of 79·2 per cent and the naphthalene-free oil 34·5 per cent. There was almost a linear relationship between the naphthalene content of the oil and the yield of phthalic anhydride.

Anthracene oil, b.p. 270-360°C., the crude anthracene cake and the anthracene-free oil separated from it, all gave almost the same yield of phthalic anhydride, of the order of 27-28 per cent, the rest of the feed being oxidized completely, thereby generating considerable amount of heat.

The yield of phthalic anhydride obtained from the naphthalene oil is considerably higher than that obtainable from the amount of naphthalene contained in the oil. Though the heat generated in oxidizing naphthalene oil is considerably more, naphthalene oil with good amount of naphthalene in it would, however, appear to be a promising raw material for the production of phthalic anhydride.

STUDIES ON DEALKYLATION OF ALKYLNAPHTHALENES, by R. N. Bhattacharya, S. P. Srivastava, G. S. Murty & H. S. Rao

Catalytic dealkylation of alkylnaphthalenes, present in tar oils and drained naphthalene oils, to naphthalene has been studied in the temperature range 450-650°C, using both fixed and fluidized bed conditions. At relatively lower temperatures using acidic catalysts (e.g. alumina-silica and alumina-boria type) and in the fluidized state, the reaction is believed to have proceeded mainly through a carbonium ion mechanism involving the isomerization of 1-methylnaphthalene into 2-methylnaphthalene and vice versa. However, the course of the reaction was found to be different at elevated temperatures, especially under fixed bed operation. Naphthalene was found to be the major product under these conditions and a free radical mechanism involving primary rupture of the allylic (Car -C) linkages is proposed. Reaction conditions for obtaining moderately good yields of naphthalene with hardly any disproportionation into dimethylnaphthalenes have been determined.

HYDRODEALKYLATION OF ALKYLNAPHTHALENES IN DENAPHTHALINIZED NAPHTHALENE OILS FROM COAL TAR SOURCES, by A. N. Bose & A. K. Ganguli.

The naphthalene oil fraction from coal tar contains appreciable amounts of alkylnaphthalenes, mainly 1- and 2-methyl naphthalenes, in addition to naphthalene. Investigations were undertaken on the possibility of converting the alkylnaphthalenes to pure naphthalene. Selected catalysts were studied under different operating conditions of temperature, pressure, time and concentration of catalyst. Results from the use of different feed materials, such as concentrated alkylnaphthalenes from coal tar sources and pure alkylnaphthalene like 1- and 2-methyl naphthalenes are discussed.

CATATYTIC VAPOUR PHASE OXIDATION OF MONOMETHYL NAPHTHALENES TO NAPHTHALDEHYDES, by Subodh K. Ray, Sisir K. Ray, G. S. Murty & H. S. Rao.

Alpha- and beta-methylnaphthalenes were subjected to catalytic vapour phase oxidation with air over a series of catalysts in a flow system in the temperature range 250-450°C. and at atmospheric pressure. Using spectroscopic and gas chromatographic techniques of analysis, quantitative values were obtained on product composition. Data on product distribution as a function of operating conditions are presented. Alpha- and beta-methylnaphthalenes on oxidation yielded alpha- and beta-naphthaldehydes respectively, along with some phthalic anhydride. A reaction mechanism has been proposed.

THE RECOVERY AND PURIFICATION OF NAPHTHALENE AND ANTHRACENE FROM COAL TAR OILS, by D. K. Sen & C. S. B. Nair.

Acetic acid has been found to be a good solvent for the recovery and purification of naphthalene and anthracene from coal tar fractions. Using 90 per cent acetic acid and crystallizing from solution under selected conditions, crude naphthalene could be upgraded to 99·7 per cent naphthalene content with an overall recovery of around 90 per cent in one step. By proper reuse of the mother liquors and washings from one crystallization step to treat a fresh lot of crude cake, it was possible to further lower the solvent requirements considerably. This procedure also enabled the recovery of naphthalene to be raised to around 95 per cent without any significant lowering in the purity level. Another group of solvents designated as 'solvols' were found to be equally effective for this purpose.

Acetic acid could be used for the upgrading of anthracene from crude anthracene cakes and anthracene oil. The high solvent requirements and the necessity to use acetic acid of different concentrations for the different steps, however, render the process less attractive. Admixture of some selected solvents with acetic acid enabled anthracene of more than 95 per cent to be obtained from a feed containing around 20 per cent anthracene in two crystallization steps. The solvent/feed ratio could be reduced to around 2 and the anthracene recovery increased to around 95 per cent by reuse of the mother liquors and washing.

*Papers Presented to the Symposium on "Chemicals & Oil from Coal", held at CFRI from 6 to 8 December 1969.

for substantial demineralization of peninsular coals. While the first generation plants are likely to be costly, especially if, as at present, high pressure equipment have to be imported, with facilities for fabrication of high pressure vessels in India now under way, costs and foreign exchange requirement can be substantially reduced in future.

We publish in two parts (in this and the subsequent issue) a feasibility study carried out by Mr D. Mukherjee and Dr A. Lahiri on commercial feasibility of conversion of coals of Assam to chemicals and oil. The study was presented before the international symposium on Chemicals & Oil from Coal held at CFRI in December 1969. Since then, the services of an eminent US expert, Dr E. E. Donath, were obtained by the courtesy of US AID. Dr Donath's study had also largely confirmed the basic findings of CFRI.

Commercial feasibility often depends on the scale of operation. For a first generation plant, which has inevitably to be on a smaller scale, the CFRI studies have indicated that production of chemicals including conversion of naphtha produced in the process into fertilizer and middle distillates, viz. HSD, kerosene as byproduct fuels, can indeed be an economic proposition even on the scale of 30,000 bbl/d equivalent of oil production.

With increasing price of oil and the need for ensuring naphtha supplies for fertilizer plants, there is a case for coal conversion with emphasis on chemicals which is worth looking into. Chemicals, which can bear higher costs than energy fuels, are likely to be more economic in a first generation plant for coal conversion. However, such a project has to be viewed in an integrated manner and must provide down-stream facilities for conversion of the chemical intermediates to finished products. Ethylene, propylene, butadiene, benzene, toluene, xylene, naphthalene, phenol, cresol, naphtha, sulphur, ashless coke and ammonia are the major products. Including conversion of naphtha to fertilizer, more than two third of the products can be grouped under chemicals which, however, account for perhaps 80-90 per cent of the sale value of the products. Such a project will initiate the technology and is perhaps as important a consideration as the long-term view taken by the Atomic Energy Commission in producing plutonium from uranium burning power plants for utilizing our enormous thorium resources for energy generation in years to come.

Yes, coal is a versatile material. It can be processed to coke, electricity, gas, chemicals and, of course, as a substitute for petroleum products. What is needed is a long-term policy for development of resources and an integrated view of the energy supply position. The coals of Assam alone constitute a potential reserve of 500-750 million tonnes of petroleum products compared to perhaps less than 150 million tonnes of natural petroleum crude so far proved.

Chief Editor: S. Ranga Raja Rao

Editor: Samir Sen *Assistant Editor*: R. S. Saha

Yearly Subscription: Rs. 4 This Copy Re. 1

Available from

CENTRAL FUEL RESEARCH INSTITUTE, P.O. F.R.I., DT. DHANBAD, BIHAR, INDIA

Phone: JHARIA 6205. Grams: RESEARCH, JEALGORA

PRINTED AT THE CATHOLIC PRESS, RANCHI

Registered with the Registrar of Newspapers for India Under No.

R.N. 3872/57

Vol. 20
No. 4

FUEL

DECEMBER
1970

IN THIS ISSUE

EDITORIAL
(Hard Coke Requirements — A Survey) - - - - - - - - - - - 91

NOBEL LAUREATE DR C. V. RAMAN PASSES AWAY - - 92

PROJECTION OF DEMAND OF HARD COKE BY FOUNDRIES AND ALLIED INDUSTRIES (OTHER THAN IRON AND STEEL) DURING 1970-71 TO 1980-81 - - - - - - - - - - - 93
N. C. Sinha, S. N. Ghosh, A. K. Moitra & A. Lahiri

PARBATPUR BLOCK, JHARIA COALFIELD — AN APPRAISAL - - - - - - - - - - - - - - - 108
S. Ghosh & S. Gupta

FEASIBILITY OF PRODUCTION OF OIL FROM COAL IN UPPER ASSAM: PART II - 112
A. Lahiri & D. K. Mukherjee

SPOTLIGHT ON SCIENTIFIC ACTIVITIES

SOUTH KARANPURA COALFIELD—AN APPRAISAL - - - - 133

UPGRADING OF SMALL COAL FROM BISRAMPUR COLLIERY - 133

EXTRACTION AND DEALKYLATION OF PHENOLS FROM COAL-OILS - - - - - - - - - - - 134

NOTES & NEWS

DR C. V. RAMAN - - - - - - - - 136

ADVISORY COMMITTEE MEETINGS FOR JHARIA CSL - - - - 137

ADVISORY COMMITTEE MEETINGS FOR BILASPUR CSL - - - 137

ADVISORY COMMITTEE MEETINGS FOR NAGPUR CSL - - - 137

TECHNOLOGY IN THE SEVENTIES: A CSIR SCIENCE REPORTERS' SYMPOSIUM - - - - - 138

NATIONAL FUEL POLICY COMMITTEE - - - - - - - - - - - 138

WESTERN REGION MINERAL CONVENTION - - - - - - - - 139

C. S. B. NAIR AWARDED Ph.D. - 139

G. S. DWIVEDI AWARDED Ph.D. - 140

VISITORS - - - - - - - - - - - 140

SHRI CHOUDHURY NITIRAJ SINGH - - - - - - - - - - - - - 140

STAFF MATTERS - - - - - - - 140

CFRI ABSTRACTS - - - - - - - 144

Hard Coke Requirements— A Survey

FOR foundry and many allied engineering industries, hard coke is the basic fuel. To sustain the continued growth of these industries, the availability of hard coke of acceptable quality is of utmost importance and the need for assuring its availability requires no overemphasis. Hence, in the knowledge that it takes anything from three to five years to establish new capacities for manufacture of quality hard coke, the CFRI made a detailed appraisal of the requirement and supply of this commodity in the context of the growing metallurgical and engineering industries in India. The result was the compilation of the report on Projection of Demand of Hard Coke by Foundries and Allied Industries (other than Iron and Steel) during 1970-71 to 1980-81, which we reproduce in this issue. In 1954 and later in 1964, the Institute undertook such surveys. The former survey led to the establishment of the Durgapur Coke Ovens of the West Bengal Government. The fillip that the coke from this plant gave to the growth of the engineering industries is well known. It not only catered for coke requirements of the foundry, ferro-alloy plants and other industries, but also often had to meet the increased demands of hard coke of the steel plants.

The present survey assumes significance in that it focuses attention on the problem and the urgent necessity for early action for installing new capacities for hard coke as, presently, almost all the merchant coke ovens have long outlived their economic life, and some badly need major reconstruction for efficient operation. Only exception is the Durgapur Plant of the West Bengal Government, two batteries of which were installed more than a decade ago. The existing three thousand and odd beehive coke ovens meet the demand of foundry coke to the extent of half million tonnes only constituting about 47 per cent in 1968-69. Arrangements for alternative and adequate sources of supply of hard coke for the various consumers have to be made. The iron and steel industry, as a rule, produces hard coke for its own use in the integrated coke ovens and only a small quantity of coke (mostly minus 25 mm) is made available to other consumers.

(*Continued on page* 111)

NOBEL LAUREATE DR C. V. RAMAN PASSES AWAY

THE death of Dr Chandrasekhara Venkata Raman, the great scientist of India and the first Indian scientist to be awarded the Nobel Prize for his famous discovery of 'Raman Effect', was deeply mourned by the Director and members of staff of the Central Fuel Research Institute. Paying warm tributes to Dr Raman with reminiscences of his association with the Institute and himself, the Director moved a condolence resolution (reported below), which was later conveyed to Dr Raman's son. Two minutes' silence was observed by the assembled members of the staff as a mark of respect to the memory of the departed soul.

Brief biography of Prof. Raman is given in the Notes and News section.

CONDOLENCE RESOLUTION

It is with profound regret that the members of the CFRI (Central Fuel Research Institute) heard over the AIR broadcast this morning (21 Nov. 1970) of the passing away of Dr Chandrasekhara Venkata Raman (Nobel Laureate) at Bangalore. The name of Raman means much to Indian science. It is he in the modern age who raised the stature of Indian science to great heights. Fittingly he was among the first to be bestowed the title of Bharat Ratna. He was the only scientist of the country to receive such high honour so far.

His attachment to work should be a great example to every one, whatever be one's field. Great confidence was his forte. When he became FRS in 1924, he told Sir Ashutosh Mukherjee with supreme confidence that he will bring the Nobel Prize to India in another 6 years time. True to his words, it was in 1930 that he was awarded Nobel Prize for Physics for his great discovery of Raman Effect in the field of molecular scattering of light. Even after his world-known work on Raman Effect, Dr Raman did not rest. He not only founded a very able School of Physics in the field of crystallography, but continued his work on diamond and, of late, on vision with great dedication. His contributions in these fields have been original and his recent theories on vision have excited the interest of world scientists.

He donated his entire Nobel Prize money to the establishment of a high calibre crystallographic research institute named after him at Bangalore. The Indian and foreign honours that he has received are a legion.

Unparalleled for his enthusiasm, devotion and capability for inspiring, the loss of Raman will be irreparable. The Director and members of staff of CFRI mourn with deep sorrow his death and pray for the eternal peace to his soul.

We remember with pleasure his visit to CFRI in 1950 to bless its inauguration.

PROJECTION OF DEMAND OF HARD COKE BY FOUNDRIES AND ALLIED INDUSTRIES (OTHER THAN IRON AND STEEL) DURING 1970-71 TO 1980-81

LIBRARY
25.8.71

Introduction

IN all discussions and deliberations on the problem of coking coal and hence of hard coke in India, the question of supply of hard coke to industries, other than main producers of iron and steel, is given secondary importance. As a result, the consumers of hard coke like foundries, rerolling mills, numerous engineering industries, ferro-alloys and heavy chemicals, etc., have till today no dependable sources of supply. Almost all the merchant coke ovens, byproduct and beehive, have long outlived their economic life. During the past two decades, the only coke plant that has come into existence is the Durgapur coke ovens of the West Bengal Government which has to cater for the hard coke requirements not only of the foundry and allied consumers but also has to meet the hard coke requirements of steel plants from time to time. By the way, the necessity of having such a plant was brought out by a statistical survey conducted by CFRI as early as in 1954*. Iron and steel industry, as a rule, produces hard coke for its own use in the integrated coke ovens and very little amount of small size (mostly minus 25 mm) coke is made available to other consumers.

It is perhaps not realized that the expansion of iron and steel industry in a country is sure to influence the development of its foundries and allied engineering industries to a great extent. In view of the extremely deteriorating conditions of majority of the existing merchant ovens, arrangements for alternative source(s) of supply of hard coke for those industries must be made without further delay. The basic requirements for planning and execution of such an alternatiue source, namely installation of modern coke plant(s), call for a reasonable estimate of demand of hard coke by industries other than iron and steel in the foreseeable future. Results of such an assessment have been incorporated in this article.

Methods of Forecasting

We have adopted three methods commonly applied in forecasting demand of an industrial commodity, viz. (a) Regression method, regression being with the independent variable ' index of production of manufacturing industries '.

We have also tried to fit the well-known mathematical model

$$y = \frac{k}{1+me^{-at}}$$

to the past data on hard coke consumption. This model provides reliable forecasting of demand of many of the industrial raw materials like steel, coal, oil, energy, electricity, etc., because of the fact that it is exponential at the beginning but gradually flattens to a saturation level. But in the particular case the ' fit ' of the model was found to be poor mainly because of continuous restrictions in actual supply of hard coke. (b) Material balance method or the method of ' norms ', i.e. on the basis of the amount of hard coke required per unit of output of main product or consumption of major raw materials. (c) Survey method, i.e. by conducting a statistical survey on an all India basis covering all the consumers of hard coke other than iron and steel.

Regression Method

As major consumers of hard coke are the manufacturing industries, indices of their production are considered as independent variable in predicting hard coke requirements by such industries. We have taken figures of despatch of hard coke†

*Survey of Hard Coke Requirement in India (excluding Blast Furnace Requirements of Iron and Steel Works), CFRI, 1954.

†*Monthly Bulletin of Coal Production & Distribution*, issued by the Coal Controller and Chairman, Coal Board.

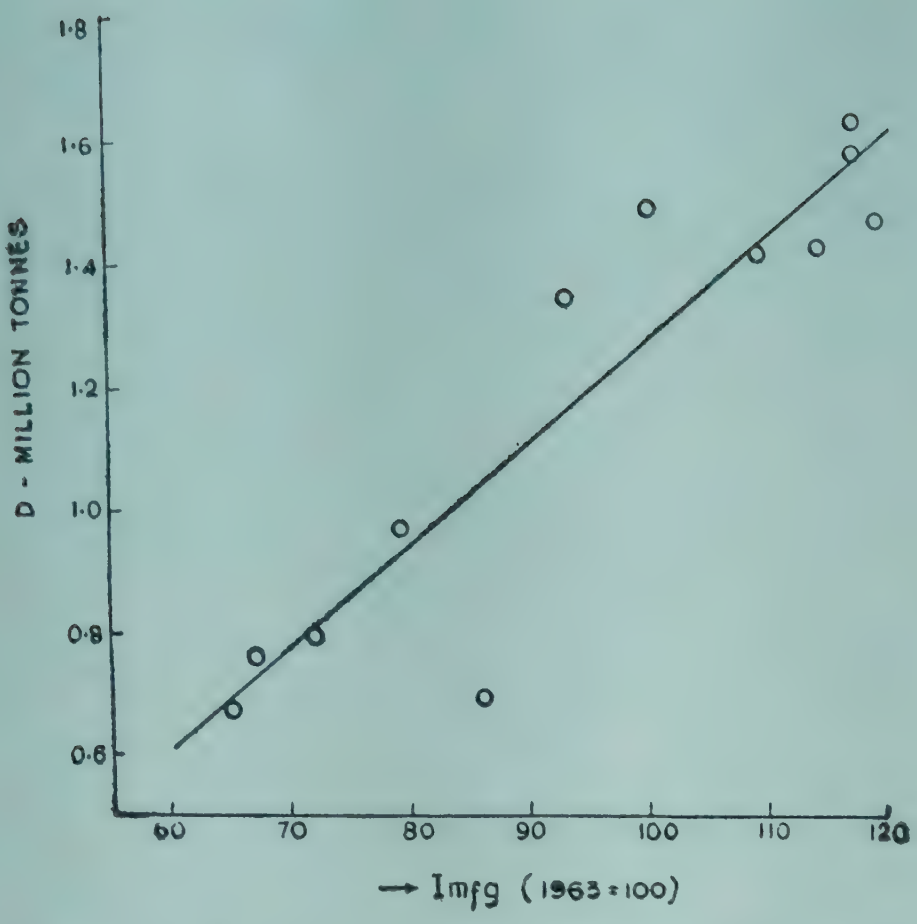


FIG. 1—INDEX OF PRODUCTION OF MANUFACTURING INDUSTRIES (I_{mfg}) VERSUS CONSUMPTION OF HARD COKE (D)

TABLE 1

YEAR	DESPATCH OF HARD COKE (million tonnes) (D)	INDEX OF PRODUCTION OF MANU-FACTURING INDUSTRIES I_{mfg} (1963=100)
1957	0·682	65
1958	0·773	67
1959	0·805	72
1960	0·985	79
1961	0·705	86
1962	1·363	93
1963	1·508	100
1964	1·433	109
1965	1·650	117
1966	1·598	117
1967	1·446	114
1968	1·486	119

from merchant coke ovens and from steel plants and chemical plants as the figures of annual consumption of hard coke. The despatch figures from 1957, together with the corresponding index of production of manufacturing industries, are shown in Table 1.

Fig. 1 shows a linear trend between index I_{mfg} and D. Therefore, a regression formula of the form $D = k + mI_{mfg}$ by the method of least squares has been fitted. The regression formula works out as

$$D = 0{\cdot}017\ I_{mfg} - 0{\cdot}4 \qquad \ldots(1)$$

TABLE 2

YEAR	ACTUAL D	CALCULATED D
1957	0·682	0·705
1958	0·773	0·739
1959	0·805	0·824
1960	0·985	0·943
1961	0·705	1·062
1962	1·363	1·181
1963	1·508	1·300
1964	1·433	1·453
1965	1·650	1·589
1966	1·598	1·589
1967	1·446	1·538
1968	1·486	1·623

TABLE 3

PERIOD	I_{mfg} @ 9% INCREASE	ESTIMATED HARD COKE REQUIREMENT (million tonnes)
1970	141	2·00
1971	154	2·22
1972	168	2·46
1973	183	2·71
1974	199	2·98
1975	217	3·29
1976	237	3·63
1977	258	3·99
1978	282	4·39
1979	307	4·82
1980	335	5·30
1981	365	5·81

the fit of this formula seems to be quite good as shown in Table 2

Equation (1) has, therefore, been utilized in estimating the hard coke requirements assuming an average rate of 9 per cent* increase in production of manufacturing industries per annum. The assessed figures are shown in Table 3.

Method of Norms

For the purpose of the assessment by this method the industries have been grouped as follows: (i) Foundries and Rerolling mills, (ii) Engineering, (iii) Soda-ash, (iv) Refractories, (v) Sugar, (vi) Vanaspati, (vii) Textiles, (viii) Cement, (ix) Glass & Glassware, (x) Paper and Paperboard, and (xi) miscellaneous including export.

Besides, there are a group of industries like ferro-alloys and special steel, ferro-

**Fourth Five Year Plan*, 1969-74 (draft), Planning Commission, Govt. of India, pp. 251.

NORM

	Requirement of coke, million tonnes								
	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81
(A									
1	0·990	1·133	1·305	1·430	1·630	1·760	1·910	2·070	2·140
2	0·256	0·301	0·357	0·420	0·458	0·497	0·543	0·591	0·647
3	0·136	0·146	0·156	0·167	0·179	0·192	0·207	0·223	0·239
4	0·111	0·125	0·141	0·158	0·177	0·199	0·223	0·250	0.281
5	0·060	0·066	0·073	0·080	0·088	0·098	0·109	0·122	0·136
6	0·010	0·011	0·011	0·012	0·013	0·014	0·016	0·017	0·018
7	0·015	0·015	0·016	0·016	0·018	0·019	0·021	0·022	0·024
8	0·003	0·003	0·003	0·003	0·003	0·003	0·004	0·004	0·004
9	0·009	0·010	0·010	0·011	0·012	0·014	0·015	0·016	0·018
10	0·007	0·018	0·019	0·020	0·021	0·023	0·025	0·027	0·029
11	0·004	0·005	0·005	0·006	0·006	0·007	0·008	0·008	0·009
12	0·161	0·183	0·210	0·239	0·261	0·283	0·308	0·335	0·366
	1·772	2·016	2·306	2·562	2·866	3·109	3·389	3·685	3·911
(B									
1	0·111	0·118	0·125	0·132	0·139	0·146	0·154	0·162	0·170
2	0·033	0·033	0·033	0·048	0·048	0·048	0·048	0·048	0·060
3	0·098	0·135	0·146	0·158	0·171	0·185	0·200	0·213	0·225
	0·242	0·286	0·304	0·388	0·358	0·379	0·402	0·423	0·455
(C									
1	0·097	0·110	0·127	0·147	0·169	0·195	0·225	0·238	0·250

are taken into account.

manganese, calcium carbide which require hard coke of high purity, low ash, low sulphur and low phosphorus content. The assessment in respect of this group of industries has been made.

The requirement of petroleum coke for expanding aluminium industry has also been assessed.

The year-wise demand of hard coke by the above group of industries during 1970-71 to 1980-81 have been computed on the basis of the established 'norms' and are given in Table 4. The information on targets of production have been compiled from the reports and publications of the Planning Commission, those of the relevant Committees and Study Groups appointed by the Government of India from time to time and of the NCAER. An industrywise outline of the results of the assessment by this method is given below.

(i) *Foundries and Rerolling Mills*: Foundries — The quantity of pig iron that may be available for sale from different sources by 1973-74 and 1978-79 has been estimated by the Department of Iron & Steel, Government of India, and are shown in Table 5.

Taking a conservative view on development of Bokaro and new plants, the pig iron available for the iron foundries may be of the order of 3·0 million tonnes and about 4·5 million tonnes by 1975-76 and 1980-81 respectively and that for 1970-71 as 1·5 million tonnes. The requirements of hard coke (Table 6) have been worked out on the basis of the norm of 0·33 tonnes of hard coke per tonne of metal.

Rerolling Mills (billets)— The rough figures of targets are 1·00, 1·60 and 2·00 million tonnes by 1970-71, 1975-76 and 1980-81 respectively. The norm is estimated at 4 tonnes of coke per 1000 tonnes of billets. The hard coke requirements for this group of industries are, therefore, 4000, 6400 and 8000 tonnes.

(ii) *Engineering* — In view of the diverse nature of products involved, indices of production of this group of industries with 1960 (=100) as the base year have been utilized for the purpose of assessment. With 1960 production level taken as 100, the corresponding indices of production for 1970-71, 1975-76 and 1980-81 works out to 260, 600 and 925 respectively. The hard coke requirements in 1960 was 70,000 tonnes; assuming requirements of hard coke at the rate of 70,000 tonnes per 100 of indices of production of engineering industry, figures (Table 7) of demand have been computed.

(iii) *Soda-ash* — The production of soda-ash during 1968-69 is estimated at 0·390 million tonnes and the target of production by 1973-74 is 0·550 million tonnes. It is estimated that the production of soda-ash in 1970-71, 1975-76 and 1980-81 may be of the order of 0·450, 0·630 and 0·900 million tonnes respectively, assuming that the production of this industry will grow at the rate of 7 per cent up to 1975-76 and 7·5 per cent thereafter. The requirement of hard coke has been estimated on the basis

TABLE 5

Sl No.	Source	Million tonnes	
		1973-74	1978-79
1	Bhilai	0·93	0·66
2	Rourkela	0·30	0·60
3	Durgapur	0·44	0·86
4	TISCO	—	—
5	IISCO	0·30	0·30
6	Bokaro	0·86	0·73
7	New Plants	—	1·23
8	Secondary producers	0·10	0·10
		2·93	4·48

TABLE 6

Year	Hot metal production (m. tonnes)	Quantity available for casting (m. tonnes)	Hard coke requirements (million tonnes) using	
			0·7 t. pig +0·3 t. scrap	0·5 t. pig +0·5 t. scrap
1970-71	9·6	1·50	0·71	1·00
1975-76	14·2	3·00	1·43	2·00
1980-81	20·0	4·50	2·14	3·00

TABLE 7

Period	Indices of production (1960 = 100)	Requirement of hard coke (million tonnes)
1970-71	260	0·182
1975/76	600	0·420
1980/81	925	0·647

of the norm of 0·265 tonne per tonne of soda-ash (Table 8).

(iv) *Refractories* — In 1968-69, the production of refractories was about 0·700 million tonnes. The requirement of hard coke per tonne of production is about 0·100 tonne. The anticipated demand of refractories in 1970-71, 1975-76 and 1980-81 being 0·883, 1·575 and 2·800 million tonnes respectively; the corresponding hard coke requirement work out to 0·088, 0·160 and 0·280 million tonnes.

(v) *Sugar* — The prodnction of sugar was 2·9 million tonnes in 1968-69. The anticipated production and corresponding requirements of hard coke are set out in Table 9. About 14 tonnes of hard coke were required in the past for the production of 1000 tonnes of sugar.

(vi) *Vanaspati* — Vanaspati manufacture (edible hydrogenated oil) requires 18 kg of hard coke per tonne. The present level of vanaspati production (0·450 million tonnes in 1968-69) is expected to rise to 1·00 million tonnes by 1980-81. The hard coke requirements are shown in Table 10.

TABLE 8

Period	Production of soda-ash (million tonnes)	Requirement of hard coke (million tonnes)
1970-71	0·450	0·120
1975-76	0·630	0·170
1980-81	0·900	0·240

TABLE 9

Period	Anticipated production of sugar (million tonnes)	Requirement of hard coke (million tonnes)
1970-71	3·5	0·049
1975-76	5·7	0·080
1980-81	9·7	0·136

TABLE 10

Period	Production of vanaspati (million tonnes)	Requirement of hard coke (million tonnes)
1970-71	0·505	0·009
1975-76	0·675	0·012
1980-81	1·025	0·018

(vii) *Textiles* — (a) Cotton Textiles: Nearly 3 tonnes of hard coke is required for manufacture of a million metres of cotton textiles. The production of cotton textiles is likely to be stepped up to 8015 million metres by 1980-81 from 4400 million metres as at present. The hard coke requirement is assessed at 0·014 million tonnes in 1970-71 (for a production of 4665 million metres), 0·016 million tonnes in 1975-76 (for a production of 5405 million metres) and to 0·024 million tonnes in 1980-81.

(b) Jute Textiles: About 2 tonnes of hard coke is required per 1000 tonnes of jute manufacture. The growth rate in production is likely to be about 3 per cent per annum up to 1975-76, and about 3·6 per cent per annum thereafter. For expected production of 1380, 1590 and 1900 thousand tonnes of jute manufacture by 1970-71, 1975-76 and 1980-81, the corresponding hard coke requirements at the past rate of hard coke utilization are 2800, 3200 and 3800 tonnes.

(viii) *Cement* — It is observed that the rate of hard coke requirements for production of a million tonne of cement is approximately about 540 tonnes. We have assumed that the growth rate of production fixed for Fourth Plan (revised) will continue up to 1975-76 and those assumed earlier for the Fifth Plan will be achieved between 1975-76 and 1980-81. The hard coke requirements as assessed are shown in Table 11.

(ix) *Glass* — The production of glass and glassware is expected to increase at the rate of 5·2 per cent up to 1975-76 and at 7·4 per cent thereafter. This industry is expected to consume 15,000, 20,000 and 29,000 tonnes of hard coke by 1970-71, 1975-76 and 1980-81, on the basis of the norm of utilization of 40 tonnes of hard coke per thousand tonnes of glass and glasswares.

(x) *Paper and Paper Board* — The target production of this industry in 1973-74 is 0·960 million tonnes as against the 1968-69 production of 0·640 million tonnes. This

TABLE 11

Period	Production of cement (million tonnes)	Requirement of hard coke (tonnes)
1970-71	14·5	8,000
1975-76	21·0	11,000
1980-81	33·0	18,000

means an overall rate of increase of 8·4 per cent and if this rate continues up to 1975-76 and increases to 11 per cent for the next five years, then the production of paper and paper board in India will be 0·750, 1·130 and 1·880 million tonnes by 1970-71, 1975-76 and 1980-81 respectively. The corresponding hard coke requirements will be 3750, 5650 and 9400 tonnes, assuming the norm of 5 tonnes of hard coke per 1000 tonnes of paper and paper board.

(xi) *Miscellaneous including Exports* — There are numerous small consumers of hard coke such as municipalities, enamel, wool, water works, power plants, steamer services, electric lights, fans, sewing machine, soap, etc., for which the norms of hard coke consumptions are not readily available. We have, therefore, assumed that these group of industries together with the provisions for export may be covered if we allow a 10 per cent cushion over the estimated total requirements for the industries under Sl. Nos. (i)-(xi).

Requirements of Hard Coke of High Purity of Low Ash, Low Sulphur and Low Phosphorus Content

There are three major industries under this group (i) ferro-manganese, (ii) ferro-alloys and special steel, and (iii) calcium carbide industry.

(i) *Ferro-manganese* — The production of ferro-manganese is likely to be of the order of 0·132 million tonnes in 1970-71, 0·176 million tonnes in 1975-76 and 0·227 million tonnes in 1980-81. The hard coke consumption per tonne of ferro-manganese production is about 0·75 tonne of low ash, low sulphur and phosphorus content. Therefore, the requirements of such hard coke will be 0·100, 0·130 and 0·170 million tonnes by 1970-71, 1975-76 and 1980-81 respectively.

(ii) *Ferro-alloys and Special Steel* — As nearly 0·5 tonne of special grade hard coke is required per tonne, the hard coke requirements have been assessed at 52,000 158,000 and 225,000 tonnes for the anticipated production of 104,000, 316,000 and 450,000 tonnes of ferro-alloys and special steel by 1970-71, 1975-76 and 1980-81 respectively.

(iii) *Calcium Carbide* — A tonne of calcium carbide manufacture requires about 0·6 tonne of special quality hard coke. Actual production in 1964 was 22,000 tonnes, which may be 55,000 tonnes in 1970-71, 80,000 tonnes in 1975-76 and at least 100,000 tonnes in 1980-81 for which hard coke requirements will be 33,000, 48,000 and 60,000 tonnes respectively.

Requirements of Petroleum Coke (Calcined)

Aluminium Industry — A tonne of aluminium ingot uses about 0·5 tonne of petroleum coke. Computing on this basis the requirements of petroleum coke work out to 76,000, 147,000 and 250,000 tonnes by 1970-71, 1975-76 and 1980-81 respectively. The production of aluminium is expected to rise up to 152,000 by 1970-71, 293,000 by 1975-76 and 500,000 by 1980-81 from the present level of 120,000 tonnes. The target for the Fourth Plan (1973-74) being 220,000 tonnes and for the Fifth Plan (1978-79) 400,000 tonnes.

The final figure of demand as per the second method of assessment is shown in Table 12.

TABLE 12

Period	Demand of hard coke (million tonnes)		Demand of coke (million tonnes)
	Foundry grade	Special grade	
1970-71	1·364	0·185	0·076
1975-76	2·632	0·340	0·147
1980-81	4·021	0·455	0·250

Figures of actual consumption of hard coke by some typical industries as reported by the Central Statistical Organization in their Annual Survey of Industries for 1964 are depicted in Table 13.

Survey of Hard Coke Requirements (CFRI, 1964)

A statistical survey was conducted in 1964 by CFRI for assessing the hard coke requirements by 1970-71 (the last year of the original Fourth Plan) covering about 2000 consumers. For this purpose an elaborate questionnaire was prepared containing specific queries on the requirements (present and future), physical and chemical qualities of coke and on other aspects of demand and supply.

It is worth while to mention here that a similar survey was conducted in 1954

TABLE 13 — MAJOR CONSUMERS OF HARD COKE, 1964*

Sl No.	Name of industry	Hard coke consumption (tonnes)
1	Internal Combustion Engines	8294
2	Textile Machinery	21255
3	Sugar Machinery	4785
4	Construction Machinery	3432
5	Rice, Dal and Flour Mill Machinery	1175
6	Size Reduction Equipment	1842
7	Power Driven Pumps	5238
8	Machine Tools	8257
9	Agricultural Implements	10,528
10	Sewing and Knitting Machines	4509
11	Ferro-alloys (Fe-Mn prod. 125,669 tonnes)	32,064
12	Iron & Steel Casting and Forging	176,580
13	Iron & Steel Structurals	7420
14	Iron & Steel Pipes	54,000
15	Non-ferrous Basic Metal Industries	12,974
16	Metal Containers and Steel Trunks	1087
17	Hand Tools and Small Tools	4413
18	Weights and Manufacture of Metal Products	6270
19	Equipment for Generation, Transmission and Distribution of Electricity including Transformers	9563
20	Electric Motors	3395
21	Electric Fans	2205
22	Electric Lamps	3457
23	Electrical Furnaces, X-ray Equipment, Electrical Machinery, etc.	1482
24	Storage Batteries	1072
25	Telephone Equipment and Teleprinters	6406
26	Ships and other Vessels Drawn by Powers	3810
27	Railway Locomotive	27,191
28	Railway Rolling Stock	36,723
29	Manufacture of Motor Vehicles	4741
30	Refractories, Furnace Lining, Bricks, etc.	17,872
31	Chinaware and Pottery	14,274
32	Insulators	4850
33	Cement (Hydraulic)	1524
34	Inorganic Fertilizers	11,465
35	Inorganic Heavy Chemicals [Production of (i) Soda-Ash, 247,972 tonnes; (ii) Calcium Carbide, 21,673 tonnes]	29,297
36	Sugar	25,016
37	Vanaspati	4075
38	Cotton Textiles	5820
39	Jute Textiles	4385
	Total	582,746

*Annual Survey of Industries, 1964, CSO Department of Statistics, Cabinet Secretariat, Government of India.

covering about 1700 consumers. The estimates of hard coke requirements and the possible deficit in supply predicted as a result of that survey have proved to be almost hundred per cent correct. The requirements for 1960 was estimated at million tonnes and the actual despatch of hard coke has been 0·985 million tonnes. The need for establishment of merchant byproduct coke ovens could only be foreseen as a result of the potential market for hard coke brought out by the CFRI survey.

As in 1954 survey, during 1964 survey also only about 400 replies were received of which 275 were found to be complete. We have considered these 275 replies as a 'random sample' representing the 'population' of 2000 consumers and analysed the information in the 'sample' for making future estimates.

Requirements in 1963 and 1970-71

Some typical replies to a few important queries in respect of selected industries are given in Table 14. It may be noted that the actual consumption (supply) was always lower than the requirements.

The total consumption of hard coke in 1963 and requirements in 1970-71 have been worked out on a different basis. The total consumption of hard coke in 1963 by 275 consumers was 142,000 tonnes which gives on an average a consumption level of 520 tonnes per consumer per annum. For 2000 consumers, therefore, it is estimated at $2000 \times 520 = 1{\cdot}04$ million tonnes. Similarly, the total requirements in 1970-71 for 275 'sample' consumers added up to 0·289 million tonnes which gives an average level of consumption as 1050 tonnes per annum per consumer. Therefore, the estimated requirements for all the industries in the group work out to $1050 \times 2000 = 2{\cdot}1$ million tonnes.

The estimate from the replies to our survey can be drawn in an indirect but more reasonable manner. The ratio of actual consumption to demand in 1963 as brought out by the survey seemed to be of the order of 0·90. The actual consumption in 1963 being 1·508 million tonnes, it means that the requirements of hard coke in 1963 was 1·65 million tonnes. Further, the survey data showed that the requirements of hard coke in 1970-71 will increase over that in 1963 by about 86 per cent. This means that according to our survey, the quantity

TABLE 14 – SOME TYPICAL REPLIES TO QUERIES FROM INDUSTRIES REQUIRING MORE THAN 1000 TONNES OF HARD COKE PER ANNUM

Sl No.	Type of industry	Number of days worked 1963	Requirement of hard coke (tonnes) 1963	Actual consumption of hard coke (tonnes) 1963	Size of hard coke (in.)	Quality of coke needed			Estimated requirement 1970-71	Type of hard coke
						Ash %	Sulphur %	Phosphorus %		
1	Foundry	365	6000	4087	+4	<20	<0·6	<0·01	9000	B.P.
2	do	300	528	836	+4	—	—	—	2700	B.P.
3	do	—	3500	1375	+4	<24	<0·6	<0·01	4000	B.P.
4	do	305	1075	455	+4	<20	<1·0	<0·01	2425	B.P./B.H.
5	do	294	395	1220	+2	<20	<0·6	<0·01	2285	B.P.
6	do	280	405	355	+4	<20	<0·6	<0·20	2000	B.P.
7	Engineering	303	2570	1672	+4	<20	<0·6	<0·01	3000	B.P.
8	do	284	4800	2368	+4	<20	<0·6	<0·2	3000	B.P.
9	do	294	1200	1013	+4	20-24	<0·6	<0·01	1400	B.P.
10	do	307	3000	2400	+4	<20	<0·6	<0·01	7200	B.P.
11	do	300	2500	1210	+4	<24	<0·6	<0·15	5500	B.P./B.H.
12	do	305	1375	473	+4	<20	<0·6	<0·15	2750	B.P.
13	do	264	7350	7350	+2	<20	<1·0	<0·15	10000	Both
14	do	272	9080	7140	+4	<20	<0·6	<0·01	10200	B.P.
15	Rolling Mills	310	1000	702	+2	<20	<0·6	<0·01	1000	B.P.
16	Sugar	120	1400	878	+2	<20	<0·6	<0·15	2000	B.P.
17	do	138	—	680	+2	—	—	—	2200	B.H.
18	do	132	1512	1021	+2	20-24	<1·0	<0·15	3000	B.P.
19	do	148	2020	1140	+4	<20	<0·6	—	2550	B.H.
20	do	166	2000	1497	+2	24-28	<0·6	<0·01	2240	B.H.
21	do	135	—	582	+4	<20	<0·6	<0·01	1700	B.P.
22	Chemicals	175	1000	557	×2	<20	<0·6	<0·01	2400	B.P.
23	do	365	16000	15483	+2	<20	<0·6	<0·20	28800	B.P.
24	do	357	8570	8570	×2	<20	<0·6	<0·01	9300	B.P.
25	Chemicals and Plastics	365	4320	1735	×1	<20	<0·6	<0·01	4200	B.P.
26	Foundry Attached to Cotton Mills	310	1300	1300	+4	20-24	<1·0	<0·15	1800	B.P.
27	Rail, Loco Works	292	3500	3420	×2	<24	<0·6	<0·20	4000	B.P.
28	do	293	3120	2099	+4	20-24	<0·6	<0·01	2640	B.P.
29	Abrasive	304	900	530	+2	20-24	<0·6	<0·01	1500	B.P.

of hard coke required in 1970-71 will be a little over 3·00 million tonnes. Considering that the tempo of industrial development as prevalent in 1963 did not foresee the economic ills of devaluation, economic recession, etc., the estimates obtained by the survey was quite reasonable and perhaps conservative. Had the earlier trend of development been continuing during and after 1965, India should have required about 3 million tonnes of hard coke in 1970-71. This means that a little above 9 per cent annual increase in hard coke production should have had taken place since 1963. The Sub-committee of the Production and Preparation Committee arrived at a figure of 2·94 million tonnes as the requirements in 1970-71 (assessed in 1964-65). Industrial development in India was almost static during the period 1965-68. The revised estimate of the hard coke requirement by 1970-71 may, therefore, be of the order of 2·2 million tonnes. If we assume the industrial growth rate of 8-10 per cent during the period 1969-74, envisaged by the Planning Commission to continue up to 1975-76, the requirements of hard coke by 1975-76 work out to 3·4 million tonnes and that for 1980-81 at 5·4 million tonnes provided that the growth rate is stepped up on an average to 10 per cent per annum from 1975-76.

Therefore, as per information collected by 1964 survey, the requirements of hard coke have been estimated (Table 15).

TABLE 15

	Requirements (million tonnes)
1970-71	2·2
1975-76	3·4
1980-81	5·4

Size and Type of Hard Coke

The sizewise demand as indicated by the survey is shown in Table 16.

It is seen that over 90 per cent of the consumers need coke of size 50 mm and above and 62 per cent require coke of size 100 mm and above.

It was also noticed from the replies that 73 per cent of the consumers exclusively required byproduct hard coke, and 50 per cent of the rest preferred byproduct coke but could manage to run their units with beehive coke. Thus, so far as the type of coke is concerned, more than 85 per cent of the consumers expressed their liking for byproduct hard coke. This is mainly due to inconsistent quality of beehive coke produced at present.

TABLE 16

Size	Percentage of total consumers requiring the size
Below 50 mm (2 in.)	9
50-100 mm (2-4 in.)	29
Above 100 mm (above 4 in.)	62
	100

Final Demand Estimates

Table 17 sets out the summary of the demand of hard coke as assessed by the three methods during 1970-80.

We, therefore, estimate that the demand of hard coke by industries other than main producers of steel by 1970-71, 1975-76 and 1980-81 will be of the order of 1·75, 3·0 and 5·0 million tonnes respectively. This includes requirements of hard coke of special quality (low ash, low sulphur and phosphorus) to an extent of 0·184 million tonnes by 1970-71, 0·338 million tonnes by 1975-76 and 0·445 million tonnes by 1980-81.

The requirements of petroleum coke for aluminium industry has been assessed at 0·076 million tonnes by 1970-71, 0·147 million tonnes by 1975-76 and 0·250 million tonnes by 1980-81. These requirements may, however, be lower if the industrial growth rate as envisaged in draft Fourth Plan by the Planning Commission fails to materialize.

TABLE 17 — DEMAND ESTIMATES

(million tonnes)

Period	By regression	By method of norms	By survey
1970-71	2·11	1·55	2·2
1975-76	3·46	2·97	3·4
1980-81	5·55	4·50	5·4

Gap between Demand and Actual Availability

The production of hard coke in the merchant coke plants for the last few years is shown in Table 18.

As stated earlier the coke ovens of the steel plants also sell small amount of coke breeze or pearl coke to this group of consumers from time to time (0·3 million tonnes in 1968-69 approx.).

In Table 19, we have compiled data giving latest information on the condition of merchant coke plants and also the likely availability of run-of-oven coke at present. The Table also brings out the fact that out of six plants, production from only one plant, i.e. Durgapur Coke Plant, should be considered as available after 1975, if not after 1970-71. If, however, these plants undertake major repair (or rebuilding), hard coke from these plants might be available after 1975-76. Therefore, the availability of run-of-oven coke may be taken as shown in Table 20.

While the deficit during 1970-71 may be said to be marginal, by 1975-76 and by 1980-81, it is likely to be serious. The minimum annual deficit by 1975-76 and 1980-81 will be of the order of 1·4 million tonnes and 3·30 million tonnes respectively, assuming that the existing 5 merchant coke plants will be out of production after 40-50 years of their existence.

Another point that need be noted here is that only 80 per cent of the run-of-oven coke is of size 50 mm. and above. We have already seen that over 90 per cent of the consumers need hard coke of size 50 mm. and above. This is likely to

TABLE 18

Year	Beehive coke	Byproduct coke (million tonnes)	Total
1963-64	0·452	0·625	1·077
1964-65	0·492	0·614	1·106
1965-66	0·553	0·594	1·147
1966-67	0·566	0·625	1·191
1967-68	0·521	0·612	1·182
1968-69	0·555	0·614	1·169

TABLE 19 — DETAILS OF EXISTING MERCHANT COKE OVENS

Sl No.	Plant and location	Year of installation	Production capacity (tonnes/p.a.)	Remarks
1	M/s Bararee Coke Co. Ltd., Kusunda, Dhanbad, Bihar	1922	66,000	The batteries are very old and it is not expected to produce more than 66,000 tonnes of coke by 1970-71
2	Durgapur Projects Ltd. (W. Bengal Govt.), Durgapur, Burdwan, West Bengal	1959	720,000	It was proposed to have a fifth battery. But the proposal is rejected and the plant is complete with four batteries. No further extention envisaged in Fourth Plan
3	Lodna Coal Co., Lodna, Jharia, Dhanbad, Bihar	1920	90,000	The company has no expansion programme during Fourth Plan
4	Bhowrah Coke Co. Ltd., Bhowra, Dhanbad, Bihar	Not available	59,400	The plant is in bad state. It is felt that this plant will cease to work in near future if no immediate steps are taken. We have taken 24,000 tonnes as available by 1970-71
5	Giridih Coke Plant, Giridih (NCDC)	Not available	50,000	The plant has outlived its normal life (55 years). There is no programme of renovation. Hence we do not consider further production in Fourth Plan
6	Barakar Coal Co., Loyabad, Dhanbad, Bihar	1921	95,000 (likely to expand to 105,000)	The plant is about 50 years old. The capacity of this plant is expected to be 105,000 tonnes in Fourth Plan

TABLE 20

Period	Availability of run-of-oven coke (million tonnes)		
	Byproduct	Beehive	Total
1970-71	0·930	0·500	1·430
1975-76	0·720	0·500	1·220
1980-81	0·720	0·500	1·220

The Gap (million tonnes)

	1970-71	1975-76	1980-81
(i) Demand of ordinary hard coke (i.e. excluding that of special coke of high purity)	1·56	2·66	4·50
(ii) Availability	1·51	1·22	1·22
(iii) Deficit (i)-(ii)	0·05	1·44	3·28

cause a further gap. But this imbalance can be expected to be narrowed down if we consider the possibility of utilization of more lower size coke which can be achieved through improved foundry practice.

The demand of hard coke of low ash, low sulphur and low phosphorus content has been assessed at 0·185 million tonnes by 1970-71, 0·336 million tonnes by 1975-76 and 0·455 million tonnes by 1980-81. Since there is no source at present, the entire quantity has to be made available from new coke oven plants of suitable capacity. Alternatively for this group of industry low temperature coke of suitable quality or formed coke of size 50-25 mm. may also be supplied.

The demand of petroleum coke is assessed at 0·076 million tonnes, 0·147 million tonnes and 0·250 million tonnes by 1970-71, 1975-76 and 1980-81 respectively. Available information on likely production of petroleum coke after calcination show that there might not be any difficulty in the supply up to 1970-71, after which new capacity has to be created.

Finding

After analysing the possible demand and supply aspects of hard coke to consumers other than the main iron and steel producers, we estimate that this group of consumers will require atleast 1·3 million tonnes of hard coke by 1975-76 and 3·00 million tonnes by 1980-81 in addition to the present level of production of about 1·4 million tonnes. In other words, this will require setting up of a new coke oven plant of carbonization capacity of 5000 tonnes of coal per day by 1975-76 and another of 6000 tonnes capacity by 1980/81. As it requires about 3-5 years for planning and erection of a new coke ovens including provision for supply of washed coals, immediate steps should be taken for the purpose, so that expansion of foundries and engineering industries may not suffer.

There is also an urgent need of establishing coke oven plant for production of hard coke of low ash, sulphur and phosphorus contents, for the ferro-alloys and calcium carbide industries for which the formed coke technique which can utilize low phosphorus non-coking coals may be useful. The coking coals almost invariably have high phosphorus.

Supply of Hard Coke — Beehive versus Byproduct

In advanced countries like England, Germany and the USA, beehive coke ovens had been installed as early as in the middle of 18th century to manufacture hard coke for metallurgical industries. Subsequently, with the increase in demand of coke for iron and steel making, the beehive coke ovens were largely replaced by byproduct ovens of larger capacities for the manufacture of hard coke as well as for the recovery of byproducts which were used for heating purposes in the steel plants. Even today, a certain quantity of coke is being manufactured in those countries by the beehive ovens for the industries which need the coke.

In India also, coke was first manufactured in beehive ovens for the iron and steel works at Kulti towards the end of nineteenth century. Since then, the number of the beehive ovens are on the increase though a large number of byproduct coke ovens of larger capacities had also been installed particularly during the last one and half decades. In 1950 the production of beehive coke in India was about 150,000 tonnes out of a total of 2 million tonnes of hard coke produced at the time. During the last two decades the production of coke from the beehive ovens had registered a small annual increase, though production of coke from byproduct ovens had increased

nearly three-fold, largely in the steel plant cokeries.

In most foreign countries the beehive ovens had often been operated as an alternative means for the manufacture of hard coke so as to fill in the gap in the production and the market demand of coke. In fact beehive coke production can help to create the new market for coke so that when the demand becomes adequate to warrant installation of byproduct coke ovens, a battery of byproduct ovens of economic size is installed and operation of some of the beehive ovens is discontinued to balance production. It is chiefly on this ground we find the need of beehive ovens to coexist in India with byproduct ovens, as they do in many other countries of the west.

The other reasons for the manufacture of hard coke by beehive coke ovens are that they produce very lumpy and dense hard coke, low in reactivity which very often is the first choice of the foundry men.

The current consumption of beehive coke in India is of the order of 0·6 million tonnes per year of which only slightly more than a third is produced from coal of good quality (ash of the coals ranging between 15 and 19 per cent) so that the ash in coke varies between 20 and 24 per cent. The balance of the beehive coke production is from relatively high ash coal and the percentage ash in coke may be as high as 30 per cent or even more. When better quality coals are used beehive produces as good a quality of coke as can be obtained from a byproduct oven. Since the coke produced from good coals in a beehive is lumpy in size, less reactive (and therefore less solution loss in a shaft furnace) and has a silvery lustre, it wins the consumer's preference even though it may fail often to conform to some other specifications for physical and chemical properties of metallurgical coke.

In a developing country like India where fluctuations in demand and availability of hard coke are inevitable, it is necessary to meet the additional increase in demand of coke by producing them in beehive ovens which therefore will serve as an auxiliary source of production of coke besides those byproduct coke ovens. Unlike byproduct ovens, beehive ovens can be brought into operation from the cold state in a very short time and can again be cooled down without any material damage to the furnaces so that the beehive ovens can be operated at will depending upon the market demands of coke. This is not possible in the case of byproduct ovens whose production can temporarily be reduced, but the ovens cannot be cooled down without serious damage to them.

Production of beehive coke is, however, objected to on certain grounds.

In the first place, it is stated that the byproducts of carbonization are not recovered and they are allowed to escape into the atmosphere leading to atmospheric pollution. The fact is that in a properly operated beehive, the byproducts are actually burnt inside the oven to provide heat of carbonization, and only products of combustion are allowed to escape into the atmosphere and should, therefore, not cause any atmospheric pollution unless the products of distillation are also allowed to escape freely. In badly operated beehives, however, some of the tarry matters do escape with flues and this leads to problems of atmospheric pollution. But this is not a normal case. In the case of byproduct oven the volatiles are recovered in the form of tar, liquor and gas. However, unless these are processed and utilized for producing fertilizers, synthetics, and high cost chemicals, the credits from the mere recovery of tar and gas (whose otherwise useful value as fuel is nominal) do not adequately balance the total overhead cost of production of byproduct coke and therefore, its cost of production is high.

The second objection against beehive coke is the coal to coke ratio which for properly operated beehives should be 1·5 as against 1·4 for the byproduct ovens. This difference is unavoidable but the ratio can be maintained at that level if the beehives are worked efficiently.

The point in favour of the beehive coke-oven is its relatively low installation and operation cost compared to that for a battery of byproduct ovens. The installation cost of a battery of beehive oven (of coal throughput of 1,00,000 tonnes per year) may not exceed Rs. 40/- per tonne of coal per year and this cost will also include certain amount of mechanization necessary to minimise labour cost. The cost of installation of byproduct oven on the other hand is about Rs. 200/- per tonne per year for a battery (of throughput capacity of 400,000-500,000 tonnes of coal per year). The

TABLE 21 — COST OF PRODUCTION OF COKE

	Beehive ovens		Byproduct ovens	
Coal throughput	100,000 t/yr		450,000 t/yr	
Coke yield	68%		76%	
Run-of-retort-coke	68,000 t/yr		342,000 t/yr	
Saleable coke (+50 mm)	64,000 t/yr		257,000 t/yr	
Capital costs including working capital	Rs. 3,600,000		Rs. 97,000,000	
Annual Debits				
(A) Raw material washed coal @ Rs. 55/t	Rs. 5,500,000	Rs. 86·00 per tonne of saleable coke	Rs. 24,750,000	Rs. 96·50 per tonne of saleable coke
(B) Operating costs, e.g. utilities, wages, fixed charges, etc.	Rs. 1,150,000	Rs. 18·00 ,,	Rs. 23,180,000	Rs. 90·00
Total (A+B)	Rs. 6,650,000	Rs. 104·00 ,,	Rs. 47,930,000	Rs. 186·50
Annual credits (small coke, etc.)	Rs. 120,000	Rs. 1·90 ,,	Rs. 12,724,000*	Rs. 49·50*
Debit Credit	Rs. 6,530,000	Rs. 102·10 ,, (say Rs. 102·00)	Rs. 35,206,000	Rs. 137·00
Cost of production of saleable coke (+50 mm) without profit	Rs. 102/tonne		Rs. 137/tonne	

*Includes tar and surplus gas.

TABLE 22 — SPECIFICATION FOR FOUNDRY COKE [IS : 4836-1968]

Sl No.	Characteristics	Requirements							
		Type 1		Type 2			Type 3		
		Grade 1	Grade 2	Grade 1	Grade 2	Grade 3	Grade 1	Grade 2	Grade 3
(i)	Porosity, per cent by weight	Up to 35	35 to 45	35 to 45	35 to 45	35 to 45	35 to 45	35 to 45	35 to 45
(ii)	Volatile matter, per cent by weight, max.	0·5	1·0	1·5	2·0	2·0	1·5	2·0	2·0
(iii)	Ash, per cent by weight	Up to 20	20 to 24	Up to 20	20 to 24	24 to 28	Up to 20	20 to 24	24 to 28
(iv)	Sulphur, on dry basis, per cent by weight, max.	0·5	0·5	0·7	0·7	0·7	1·0	1·0	1·0
(v)	Phosphorus, on dry basis, per cent by weight, max.	0·1	0·1	0·15	0·15	0·15	0·3	0·3	0·3
(vi)	Shatter index, for material								
	(a) Over 75 mm per cent by weight	35	30	30	25	25	25	25	25
	(b) Over 50 mm per cent by weight, min.	80	75	70	70	70	70	70	70

above cost excludes the cost of auxiliary units required for the processing of tar, etc. If we include these costs, the capacity throughput of the plant has to be raised to enable recovery of sufficient quantity of tar to warrant an economic tar processing unit to be installed. In such a case the throughput capacity of byproduct oven has to be about 3000 tonnes of coal per day at least for obtaining adequate quantity of tar for processing. In all such cases there should be scope of utilizing the

surplus gas in nearby industries especially for the production of fertilizers and chemicals so that full credit can be derived from the sale of gas. If there is no use of gas as raw material in ancilliary industries, it gives little credit if it has to be burnt as a fuel. It is, therefore, seen that only when the byproducts (tar, liquor, benzol and gas, etc.) are recovered and gainfully utilized for the production of useful chemicals, etc., their higher sale value brings sufficient credit and helps to reduce the overheads on the cost of production of byproduct hard coke. Production cost of beehive coke is unlikely to be higher than byproduct hard coke where adequate credits are not obtained from byproducts. The production cost of coke from a byproduct oven where tar is recovered and sold as such and the gas used as fuel is bound to be higher than that for coke produced in a beehive oven because of present day high cost of installation of byproduct coke ovens, and since the depreciation cost etc. has chiefly to be borne by coke. Even at Bokaro Steel Plant with coke oven of capacity 2·5 million tonnes per annum, it was considered uneconomical to recover benzol from coke oven gas for further processing. A rough idea of likely cost of production of hard coke by both the methods are given in Table 21, on the basis of the washed coal price at Rs. 55/- per tonne and taking into consideration the present cost of installation of these units.

Specification for Hard Coke

At present there is no Indian Standard Specification for beehive coke. Table 22 reproduces the requirements for foundry coke as per Indian Standard Specifications (IS: 4836-1968). If beehive coke, manufactured from consistent quality coal, conforms to the specification, the foundry industry will have no hesitation in accepting the same. A rational price policy, depending on the quality, should however, be evolved which is sure to provide incentive for production of quality coke. The quality grade foundry coke even from beehive ovens will be able to capture some foreign market, especially in ECAFE countries.

N. C. Sinha, S. N. Ghosh,
A. K. Moitra & A. Lahiri

ERRATA

1. **D. K. Mukherjee's name has not been printed along with A. Lahiri as author of the first article "IN THIS ISSUE" in June-September 1970 issue of the *FRI News* due to oversight.**
2. **The price of the June-Sept. 1970 issue of *FRI News* should be Rs. 2/- per copy instead of Re. 1/- per copy which was wrongly printed.**

PARBATPUR BLOCK, JHARIA COALFIELD—AN APPRAISAL

THE progressive expansion planned for the iron and steel industries require a proportionate enhancement in the supplies of metallurgical coal to these industries. A fresh search for locating new sources of coking coal was, therefore, considered necessary. In the Jharia coalfield, the only known source of parent coking coal, the Barren measure zone, was expected to be such a source and its exploration was entrusted to the National Coal Development Corporation (NCDC).

The detailed exploration by the Corporation was started in 1957 following regional proving by the Geological Survey of India (GSI). The results of systematic survey on coal quality and properties undertaken by the Central Fuel Research Institute (CFRI) through its Jharia Coal Survey Laboratory provided a guide for anticipating the properties of coal in seams in the zone explored. The survey had established a trend of lateral and vertical variation of volatile matter in the coals of the Jharia coalfield which on projection indicated that the seams, even at depth in the south-eastern zone unlike the central and western part, will contain coal of good coking properties.

The NCDC which had earlier explored the western and central part of the zone, north of the river Damodar, on the suggestion of the CFRI extended its exploration to the Parbatpur block lying to the south of the river.

The Parbatpur block lies in the eastern part of the Jharia coalfield bounded by lat. 23°42′06″ and 23°39′30″N.; and 86°19′15″ and 86°23′28″E long., covering a total area of 5035 acres and is situated west of Amlabad-Bhowrah area.

The prediction of the CFRI has proved to be correct and justified from the results of the detailed prospecting by the NCDC and study of the use potential of the coal carried out at the JCSL of the CFRI. The block is now estimated to contain over 750 m. tonnes of reserves of good coking coal and is thus a major addition to the limited reserves of good coking coal of India. The property will be developed by the NCDC on whose behalf the detailed studies of the coals from the block were carried out by the Institute.

Structure

The Jharia basin can be broadly divided into three parts. The northern part comprises the main synclinal basin with the Raniganj measures of Mohuda area in the centre. The southern part comprises another synclinal basin extending in the Mahal-Bhojudih area. In between these two synclinal basins there is a zone of uplift or an anticlinal area extending from Aluara to Patherdih through Amlabad and Bhowrah. Both the synclinal basins as also the anticlinal area have more or less EW parallel areas plunging to the west.

The Parbatpur block is situated in the anticlinal area, its northern flank dipping northwards forms the southern limb of the northern main basin and the southern limb dipping south forms the northern limb of the southern syncline.

There are a number of faults in the area comprising two sets. The first set comprises cross-faults trending NS and usually covering long distances, while the second are strike faults trending EW and covering shorter distances. There are some major faults, with throws of even up to 200 metres.

The amount of dip is generally between 10° and 12°. Over most of the area except in the southern part where it may increase to about 20° and in the east-central region where it is flatter ranging between 3° and 7°. The general strike direction is WSW-ENE. The northern limb dips northwards and the southern limb dips southwards.

A fairly large area of the block is much less disturbed compared to some areas where the structure is more complicated.

Stratigraphy and Coal Seams

The major part of the area is covered by the Barren measures and some parts in the central uplifted region are covered by upper Barakars. Drilling was mainly confined to the proving of up to XII seam and only in few cases was extended deeper and only one borehole penetrated the entire sequence of Barakars.

The drilling proved the presence of 24 coal seams (including the split sections) within the Barakar measures, of which 13 are

workable seams (XVIII top to XII including splits and local seams) which contribute to the potentiality of the block. The upper horizons (XVIII top to XVA) are comparatively thinner, less than 4 metres thick, and the lower horizons (XV-XII) have a usual thickness between 5 and 16 metres.

Igneous Intrusives

Igneous intrusives (mica-peridotite) have affected many seams and have converted them to *jhama* partly or wholly. The areas most affected are the north, north-east and east. Generally, the higher horizons have been more affected than the lower horizons except seam XII which has been affected quite extensively. The most heavily affected seams are XVI, XIV, XIII and XII. Southern part is almost free from effects of intrusives.

Reserves

Reserves of coal have been calculated for seam thickness (isocore) more than 1·2 metres, *jhama* has been excluded. Volatile matter of 20 per cent (on unit coal) and above have been considered for the calculations. The total reserve of coal from all the workable seams XVIII top to XII within the block is given in Table 1.

TABLE 1 — RESERVES

(in million tonnes)

	Reserves up to 700 m. horizons	Reserves in 700 to 800 m. level	Total
Coals with V.M. of 22% (unit coal) and above	677·45	11·58	689·03
Coals of above quality occurring below Damodar river	13·37	3·20	16·57
Coals with V.M. (unit coal) of 20-22%	53·24	5·39	58·63
Total	744·06	20·17	764·23

Quality of Coal

From the point of thickness (hence reserve) and quality, the seams can be divided into two groups. The first group with less than 4 m. thickness consist of XVIII-XVA seams and the second group with appreciably more thickness (5-16 m.) consisting of XV and lower seams. Of these, the coal from XVIII bot., XVII, XV top and XV combined are better in quality than the rest. These seams contain coal with ash even including dirt bands not exceeding 17 per cent. The XVIII top and XV bot. seams contain coal with ash between 17 and 24 per cent including bands. The coal from other seams are dirtier.

The detailed properties of coal from these promising seams are given in Table 2.

TABLE 2

	Thickness	Ash%		D.M.F. basis			Coke type
		Ex. bands	Incl. bands	Vols %	C%	H%	
XVIII bot	1·0-1·2	13-17	(mostly no bands)	31-33	88-89	5·1-5·3	G-G_4
XVII	2·0-3·0	15-17	16-19	32-34	88-89	5·0-5·2	G-G_4
XV	8·5-13·5	15-17	16-20	26-28	—	—	(25-30)C.I.
XV new	1·0-1·8	10-13	no bands	23-26	—	—	(18-25)C.I.
XIVA	3·0-5·0 (N) 8·0-13·0 (rest)	18-20	23-28	24-28	90·5-91·0	4·7-4·9	G-G_2
XIII	5·0-8·0	17-20	19-24	23-25	91-92	4·6-4·9	F-G at 700 m. D-E below 800 m.

Note — The seam XIII is heavily affected by intrusives. The analyses refer to unaffected coal portion also. Although XVII bot. and XV new seams contain quite low ash coal, it is doubtful whether the quality of coal in mechanically mined product can be maintained to such a level.

The other seams though thick (4-10 m.) contain coal usually having ash 20 per cent and above with dirt bands excluded and 4-6 units higher with the dirt included. The XVI top and bottom, XIV (in the northern region) and XII seams are heavily affected by intrusives.

The volatiles (dmf) in the coal from these seams are above 22 per cent up to a depth of about 700-800 m., that from the XII seam (where unaffected) being around 22 per cent.

The seam XI is 7-10 m. thick. Seams X and IX usually have 4-5 m. thickness and contain inferior coal usually with ash 20 per cent and higher (ex. band) and 4-6 units higher with all dirt bands included. The volatiles (dmf) in the coal from these seams are usually less than 22 per cent and lie between 18 and 22 per cent. Their potentiality as parent coking coal is doubtful and these might be utilized as good blendable coal.

There is a general tendency for the volatiles (dmf) from the coal at similar depth from all the seams to increase in the south-eastern region. The drop in volatiles (dmf) is around 0·5-1·0 per cent for each 100 m. of depth.

Coking Properties

The coal from all seams from No. XIV to XVIII have high C.I. (generally above 20), high fluidity and swelling index (6-7½). The seams underlying XIV contain coal with fairly high C.I. (16-20), low fluidity and lower swelling index (3-1½).

The coal from seam XIV and above gave coke type G and above (up to G_8) but the lower seam coals gave inferior coke type. The good coking potentiality of these upper seams as judged by volatiles (dmf), coke type and fluidity is maintained up to a maximum depth of about 700-800 m. where these have been proved. The major reserves as proved appear to occur up to a depth of about 700 m.

Cleaning Possibilities

Although some of the seams contain coal with ash acceptable for metallurgical coal yet large scale machine mining is sure to contaminate the coal with dirt and lower the quality. Cleaning will, therefore, be necessary to maintain the ash of the mined product to a consistent acceptable level. Exploratory washability tests on crushed coal (13 mm. top size) indicate that yields of 70-80 per cent of cleans with 10-14 per cent ash at sp. gr. 1·50 might be expected for coal from XIV and above (except XVI bot), while the coal from the underlying seams yields 50-70 per cent with 14·5-16 per cent ash at sp. gr. 1·50. The yield of cleans can be improved by blending these with the clean dust (0·42 mm. and lower), which amount to about 2-6 per cent having 10-16 per cent ash.

The cleans from seams up to XV bot. have improved caking property as measured by C.I. and coke type (l.t.c.), and low phosphorus (0·10 and lower).

The high carbonate minerals which generally accompany the coal from nearly all these seams are concentrated in the middlings, the carbonate CO_2 being as high as 11·7 per cent, and usually 2 per cent and above. The middlings (between 1·50 and 1·80) amount to 10-20 per cent with 30-35 per cent ash. The volatiles (above 20 per cent), and calorific value (5000 kcal/kg and above) make these suitable for use in power generation but the low initial deformation temperature of ash (generally around 1100°C) and fusion temp. often below 1350°C, may call for suitable design of furnace for the boilers.

Observation

The block contains large reserve of potential parent coking coal. The caking properties have been maintained up to about 800 m. in seams XIII and above. The seams underlying XIII have either been heavily damaged by intrusives, or contain inferior coal with volatiles below the limit acceptable in parent coking coals.

The total reserve of seams containing parent coking coal [with volatiles (dmf) 22 per cent and above] amount to about 705 m. tonnes up to 800 m. Assuming 60 per cent extraction, on washing, these are expected to yield about 250 m. tons of coal as directly usable in the iron and steel industries.

The middlings though high in calorific value (around 5000 kcal/kg) and having about 20 per cent vols, which make them suitable for use in thermal power station, have concentration of carbonate minerals which bring down the fusion point of ash. This will call for consideration in the design of furnaces for boilers in thermal power generation.

A total reserve of about 58 m. tons of coal with 20-22 per cent volatiles (dmf) will be available as good blendable coal. The total net reserve that will be available will amount to 20 m. tonnes.

The seams XI and lower contain caking coal which are very inferior and have volatiles (dmf) below 20 per cent. The expected cleans yield on washing will be around 50-55 per cent. These may also be utilized in blends with suitable matching coals.

S. GHOSH & S. GUPTA

References

1. Reports on Parbatpur Block by the NCDC, 1968.
2. Annual Reports of the Jharia Coal Survey Laboratory for 1964-67.
3. Technical Reports of the Jharia Coal Survey Laboratory Nos. IV/65, V/66 and V/67.

Hard Coke Requirements—A Survey —*Contd from page* 91

For forecasting the demand of hard coke by foundries and allied industries (other than iron and steel) for the next decade, the survey has adopted three different methods, viz. questionnaire survey, the method of norms and the regression method. The industries considered were: foundries and rolling mills, engineering, soda ash, refractories, sugar, vanaspathi, textiles, cement, glass and glassware, paper and paper board and miscellaneous including export. Hard coke with special properties is required by ferro-alloys and special steel industries, ferro-manganese and calcium carbide manufacturers. Assessment of the requirement under these categories has also been made.

These assessments have shown that consumers, other than iron and steel producers, will require at least 1·3 million tonnes of hard coke by 1975-76 and 3·00 million tonnes by 1980-81 in addition to the present level of production of 1·4 million tonnes. This clearly indicates that to meet their demand, it will be necessary to set up a new coke oven plant of carbonizing capacity of 5000 tonnes of coal per day by 1975-76 and another 6000 tonnes capacity by 1980-81. As it requires about 5 years for planning and erection of a new coke oven including provision for supply of washed coal, immediate steps should be initiated lest the normal operation and growth of foundries and engineering industries should suffer a setback for want of a basic raw material, namely coke. In this connection, we wish to draw attention to the CFRI projected plan (1965) for establishing a coke oven based industrial complex in the Ramgarh area of the BRK coalfields. The need for taking up this for urgent consideration is obvious.

The survey has also indicated that the demand of hard coke of low ash, low sulphur and low phosphorus for alloys and calcium carbide will be 0·185 million tonnes by 1970-71, 0·336 million tonnes by 1975-76 and 0·455 million tonnes by 1980-81. There is no indigenous source at present for meeting this demand. The entire quantity has to be met from new coke oven plants by careful selection and processing of available coals. Low temperature coke or formed coke can also meet this demand. The time is, therefore, opportune to make a beginning by establishing a suitable LTC and/or formed coke plant for the purpose, perhaps in the Madhya Pradesh area where low phosphorus and low ash coals are available in some quantities.

The demand for petroleum coke, the preferred fuel for aluminium manufacture, is estimated at 0·147 and 0·250 million tonnes annually by 1975-76 and 1980-81 respectively. The shortfall in its indigenous availability anticipated by 1980-81 is of the order of 94600 tonnes. The cost for importing this is likely to be Rs. 61·5 million. Manufacture of pitch coke from surplus tar available in the country offers a solution in this context. The CFRI is also exploring alternative routes, e.g. by solvent extraction of coal.

(*Contd on page* 135)

FEASIBILITY OF PRODUCTION OF OIL FROM COAL IN UPPER ASSAM: PART II*

The Potential and Need for Chemical Production

IN the preceding chapter on basic cost economic considerations, we have dealt with a few major items, i.e. capital investment (capital charges), coal, hydrogen, etc. But profitability will also depend on the end product pattern, their values and markets.

A coal hydrogenation plant can produce not only chemicals that can be normally produced in a petroleum refinery, but also others such as ammonia, phenol, cresols, nitrogenous bases, etc., which are, in a way, byproducts, and whose removal or conversion involves low costs. Also, due to basic aromatic structure of coals, the potential for aromatic chemicals from coal is higher and production costs cheaper. Further, the product pattern in a coal hydrogenation plant can be very flexible. A separate study is under way to consider how the product pattern can be changed to produce primarily chemicals and how it will affect profitability.

The aromatic chemicals and other byproducts can substantially subsidize the costs of energy fuels as well. Provision could be made for production of premium gasoline and fuels of the future, e.g. for supersonic jets.

In the study presented here, out of 3 million tonnes of products, nearly 0·66 million tonnes are derived as byproduct chemicals (including coke), the sale value of which covers nearly 80 per cent of the annual operating expenses including capital charges.

None of the fuel products can as such compete in value with any of the byproducts. For example, against an estimated ex-refinery costs of Rs. 242 per tonne of normal grade motor gasoline, even calcined petroleum coke in India sells at Rs. 500 a tonne, and in view of the demands and expected shortages, the prices are not likely to fall. Synthesis grade benzene, produced by hydrogenation, is likely to sell at Rs. 1000 a ton. Phenols, which are specialities of a coal-to-oil refinery, also has a value of the order of Re. 1/lb., i.e. more than Rs. 2000/ton. Therefore, consistent with the market demands for chemicals and fuel products, a coal-to-oil refinery, especially of smaller capacities, must be a fuel-cum-chemical complex, especially in India, where the naphtha cannot be sold except at a distress price. Premium energy fuels can help, but cannot basically alter this overall economics.

Aromatics

The major chemicals that can be obtained from the coal-oil refinery are, of course, aromatics. Table 10 compares the paraffin, naphthene and aromatic contents of naphtha from some of the German plants,

TABLE 10 — ANALYSIS OF NAPHTHA

(Per cent vol.)

	Scholven†	Gelsenburg†	AMCO[10]	Nahorkatiya[11]
Paraffin	37·5	36·5	24	51
Naphthene	53·0	54·9	61	26
Aromatic	8·5	9·0	15	23

†Report on the Petroleum & Synthetic Oil Industry of Germany, The Ministry of Fuel & Power, London, U.K.

*Continued from *FRI News*, June-Sept. 1970, p. 66.

of H-coal naphtha and naphtha from Nahorkatiya crude.

The naphthenes are precursors of aromatics. C_6 naphthenes will yield benzene; C_7 and C_8 naphthenes will be converted to toluene, xylene and ethyl benzenes; C_9 naphthenes will produce trimethyl benzenes and so on. Other potential chemicals available in a coal-to-oil complex are ethyl benzene, durene, pseudocumene, anthracene, phenanthrene, acenaphthene, pyrene, nitrogen heterocyclics and large quantities of naphthalene. Additional benzene, if desired, could be obtained by dealkylation of toluene and xylenes. The xylene distillates can be fractionated to produce ethyl benzene and xylene isomers. The high potential yield of aromatics enables withdrawal of product either for sale as high octane gasoline or for production of chemicals.

It is interesting to note that the potential yields of BTX from coal hydrogenation is of the order of 105 kg per tonne of coal as against 7·3 kg per tonne from carbonization of coal. However, the amount of aromatics that can be produced will be limited by the market and/or plans for utilization of aromatics at site for production of various finished products, such as styrene, phthalic and maleic anhydride, pesticides and a large group of other synthetic chemicals, rubber, polymers, etc. In such a complex, residual quantities of naphtha but after aromatic recovery will also be fully and profitably utilized. These are, however, outside the scope of this project study.

The demand for pseudocumenes for production of trimellitic anhydride for conversion to water-soluble alkyd resins, esters for vinyl plasticizers, poly-amide resins and ester-imide resins is also likely to come up in future as indeed it has in other countries. Durene which is also available can be used to produce pyromellitic anhydride for new types of poly-esters and poly-imides by reaction with glycols and di-amines. Use of poly-imides is increasing for application in heat-resisting ware enamels and for use of plastics under higher temperature conditions.

Other polynuclear aromatics, such as acenaphthene, anthracene, phenanthrene, carbazole, pyrene, etc., have limited uses but if they can be produced at reasonable cost unlike from coaltar sources, they will have important uses, though in limited quantities.

Phenolics

Another series of important chemicals that can be obtained at will are the 'tar acids' or the phenolics. The increasing requirement of cresols and cresylic acid throughout the world and/or phenol and their high costs make recovery of these chemicals a very attractive proposition in a coal-to-oil refinery. The potentialities are practically unlimited in so far as 4-5 per cent of the coal can be obtained as phenolics, but its recovery will be restricted by available market. The *m*- and *p*-cresols are particularly in short supply the world over and the liquid phase hydrogenates could be an important source for meeting not only the local demand but for export. The ortho-cresols are important for production of herbicides, but the greater demand for cresols is for phosphate-ester production and for modifiers, antioxidants and flavouring agents. The US consumption is expected to be more than 200 million lb/year by 1970 and a rise of 10 per cent thereafter. The demand over supply of cresylic acid has led to its production by alkylation of phenol and by propylation of toluene. Costwise also *m*- and *p*-cresols are more than $1\frac{1}{2}$ times the cost of phenol. In our techno-economic study, we have allowed for only a limited production of total potential availability. Cresylics could be a substantial foreign exchange earner.

Naphthalene

Another major aromatic chemical which can be obtained from coal hydrogenates in large quantities is naphthalene. For example, the potential availability from a 50,000 barrel/day coal-to-oil refinery has been estimated to be of the order of 200 million kg per year. The naphthalene produced from coal hydrogenates is extremely pure and is suitable as such either for fluid bed or fixed bed synthesis of phthalic anhydride. The source of naphthalene in coal hydrogenates is hydronaphthalenes, unlike alkylnaphthalenes in petroleum distillates and since dehydrogenation is cheaper than dealkylation, production cost of naphthalene from coal hydrogenates will also be considerably lower. Naphthalene should be present in the C_6-C_9^+ cut-off naphtha and the distillate residues should yield most of the tetralins and decalins required for production of naphthalenes. The relative

utility of orthoxylene and naphthalene for production of phthalic anhydride is a matter of costs. Cheap naphthalene from coal hydrogenates will, therefore, have an edge over orthoxylenes. The major utility for naphthalene is, of course, phthalic anhydride but substantial quantities of systemic insecticides and fungicides are also produced and are required in large quantities in India. In addition, it has its use for production of naphthols, syntans, etc.

Tar Bases

Coal tar bases, such as pyridine and picolines, are reported to be present in the naphtha fractions from coal hydrogenates. Their recovery has not been reported as yet, but presumably this may follow. Picolines are especially valuable for production of pharmaceuticals and drugs. Pyridine has numerous uses including solvents, vitamins, waterproofing material, anticorrosion compounds, etc.

Sulphur and Ammonia

Since Assam coals contain high organic sulphur, practically the entire quantity of organic sulphur will be recovered as H_2S. H_2S will also be required for recirculation for maintaining catalyst activity and hence high sulphur in coal is an advantage. H_2S can be either converted to elemental sulphur or to sulphuric acid. Per ton of coal hydrogenated approximately 11·5 kg ammonia will be produced which, in turn, will require 32·8 kg of sulphuric acid for conversion to ammonium sulphate. Since ammonium sulphate is the preferred fertilizer for the tea industry, a substantial part will be used in fixation of ammonia and the remainder can be sold to the present ammonium sulphate plant in Assam where imported sulphur is used. Production of sulphur and ammonium sulphate is a major attraction for hydrogenation of Assam coal.

Ashless Coke

Another product which is in demand (and the demand for which will increase in future) is ashless coke of electrode quality. Even in the IV Plan, there is an anticipated shortage of about 60,000 tonnes per year. Over 80,000 tonnes of petroleum coke will be produced in the 30,000 BPD coal refinery out of a total of 150,000 tonnes/year from the combined refinery.

Olefines

A coal-to-oil refinery can produce the whole range of petro-chemicals in addition to aromatics, phenolics and nitrogenous heterocyclics. Ethylene, propylene and butenes are some of the standard building blocks in polymer chemistry which can be produced by direct recovery from the cracker gases, and their quantities could be increased by dehydrogenation of ethane, propane and butane obtained from gases of various sections of the hydrogenation plant.

Olefines are not present as such in appreciable quantities but are obtained in dehydrogenation processes. Nearly 20-25 per cent of carbon in coal appears as hydrocarbon gases distributed equally over C_1-C_2-C_3 hydrocarbons. The combined stream of gases produced from several sections are cryogenically separated and utilized for production of respective end-products. The liquid products also contain higher molecular weight olefines, including olefines obtained from higher boiling gas fractions. These could be a source of oxo-products. The hydrogen produced is welcome. The methane and hydrogen in the original gas along with those produced from dehydrogenation are returned to the hydrogenation process itself through steam reformer.

An American estimate places the credit from chemicals from a 50,000 BPD as given in Table 11

For an additional investment of $ 20 MM credits from the chemicals have been estimated to amount to $ 20 MM annually with gasoline selling at 12·0¢ per gallon The estimate include credits from ammonia, sulphur but not coke. Earlier estimates by the US Bureau of Mines and Ebasco and Bechtel had indicated that out of the total product revenue, more than 35 per cent may come from aromatics and tar acids, about 10 per cent from ammonium sulphate and sulphur and only about 55 per cent from motor fuels and LP gas. This feasibility study also indicates that chemicals and byproduct credits constitute 62 per cent as against 38 per cent only for middle distillates and naphtha.

It is, therefore, evident from our techno-economic survey that with current level of technology and costs, a pure liquid fuel refinery from coal alone for less than 100,000 BPD capacity may not be competitive

TABLE 11 — PRODUCT VALUES AND INVESTMENTS FOR CONVERSION OF COAL UNDER U.S. CONDITIONS

(Capacity: 50,000 BPD)

Products	All fuel			¾ Fuel, ¼ Aromatics			Fuel, Aromatics, Tar acids			Fuel, Aromatics, Tar acids, Naphthalene		
	MM gals.	Price	Value $ MM	MM gals.	Price	Value $ MM	MM gals.	Price	Value $ MM	MM gals.	Price	Value $ MM
Gasoline	663	12	79·6	490	12	58·5	480	12	57·6	450	12	54·0
Fuel oil	0·5 MM bbl.	$2/bbl.	1·0			1·0			1·0			1·0
Benzene				84	20	16·8			16·8			16·8
Toluene				18	20	3·6			3·6			3·6
Xylene				38	21	8·0			8·0			8·0
Tar acids							80 MM lb		9·6			9·6
Naphthalene										250 MM lb		7·5
Total value			80·6			87·9			96·6			100·5
Investment, $ MM		227			237			245			247	

Ref.: Private communication, Office of Coal Research, USA.

with petroleum products. On the other hand, with a product pattern allowing for reasonable recovery of aromatics and other chemicals and byproducts, even a 30,000 barrel/day coal-to-oil refinery may be economic, especially if it is combined with a natural petroleum refinery based on hydrocracking and hydro treatment, a possibility which can materialize only in upper Assam.

Gasoline and Naphtha

The crude oils of Assam, as will be evident from Table 12 and Appendices 7 and 8, have excellent potentialities for production of high octane gasoline[11]. Since the major demands are for middle distillates and aromatic-rich naphtha is less suitable for use as feed stock for hydrogen for ammonia plants, its potential for meeting national demands is poor. A radical change in the refinery pattern (than what is being followed at Gauhati or Barauni leading to heavy loss of oil as SO_2 extract as shown in Appendix 9) by hydrocracking of the heavy residues and hydrotreatment of middle boiling straight-run and coker distillates is necessary.

The potential of recovery of aromatics from the syncrude is considerably higher than natural petroleum. Hence, a combination of syncrude and natural crude refining will have major advantages for both. As many of the product fractions will have similar properties, their combined treatment will enable larger size units to be used. Other economies that can be obtained have already been mentioned.

Petro-chemicals

There is a proposal at present for setting up of a petro-chemical complex in Assam. There is also demand for locating a refinery at well-head, for which it has been stated that availability of crude is not sufficient for a refinery of economic capacity. Production of syncrude on the scale of 30,000 barrels/day and combined with refining of natural crude will not only enable an economic refinery and a petro-chemical complex to be built, but lay the foundations for future production of syncrude and liquid fuels and chemicals, ammonia and sulphur from coal on an increasing scale from the large reserves of the unique coals that are found both in north and south Assam. Piping of products is cheaper than piping of crude. To the nation, the actual costs and self-sufficiency are that matter and

TABLE 12 — COMPOSITION OF NAHORKATIYA GASOLINE

[Hydrocarbons* (b.p. below 160°C); vol. % of total distillate from 42 to 180°C]

Hydrocarbons	Approximate volume %
Paraffins	
Dimethylbutanes + Methylpentanes	3·8
n-Hexane	8·8
Dimethylpentanes + Methylhexanes	6·7
n-Heptane	6·2
Dimethylhexanes	4·6
Methylheptanes	0·5
n-Octane	2·7
Dimethylheptanes	4·5
Methyloctanes	2·4
n-Nonane	1·2
Dimethyloctanes	1·6
Naphthenes	—
Cyclopentanes	0·0
Methylcyclopentane	0·3
Cyclohexane	3·1
Dimethylcyclopentanes	1·4
Methylcyclohexane	3·6
Alkylcyclopentanes (C_8) + Alkylcyclohexane (C_8)	7·1
Alkylcyclopentanes (C_9) + Alkylcyclohexanes (C_9)	7·0
Aromatics	
Benzene	2·9
Toluene	4·0
Ethylbenzene	0·4
p-Xylene + *m*-Xylene	6·1
o-Xylene	3·2
Isopropylbenzene	1·6
n-Propylbenzene	1·6

*The concentrations of benzene and toluene were determined by ultraviolet and infrared spectrophotometric analysis, while those for other hydrocarbons are the cumulative values of those reported in Table 3 for the different fractions.

Ref.: Structure and Composition of Nahorkatiya (Assam) Gasoline, H. S. Rao, G. S. Murthy, P. L. Gupta, N. R. Subbaratnam & A. Lahiri, *J. scient. ind. Res.*, (1959), **18B**, 379-86.

not the price of petroleum in the Persian Gulf.

The location of resources and the unique combination of existence of coal, oil and gas in one area in itself calls for a bold approach and experimentation, and it is hoped that the preliminary feasibility study presented here will arouse interest of our leaders and planners.

CHAPTER V

Reserves and Quality of Coal

Table 4 gives estimates of *in situ* reserves of coal in lower and upper Assam.

Seven coal seams are met in the Makum and Namchik-Namphum area. The sulphur content of coal varies both from seam to seam and place to place. Appendix 11 shows the sulphur content and other properties of six important coal seams occurring in the area over a straight line of nearly 240 km stretching from Divale river in the west to the hairpin bend of Tirap river in the east and possibly farther beyond. In respect of high organic sulphur, the coals are unique in India.

The coalfield has been surveyed for several years in great detail by the Coal Survey Laboratory of the CFRI located in north Assam in Jorhat. Assessment of the quality of coals is now in progress from the point of view of its suitability for hydrogenation and washability. Thirty per cent recovery with 3-4 per cent ash is normal. Tar yields increase in clean coals. Pyritic sulphur is reduced during washing, but percentage of organic sulphur in coal increases proportionately. However, there will be a considerable concentration of sulphur in both middlings and rejects, major part of which may be pyritic. No consideration has been given for recovery of sulphur from the power plant.

Constitutionally, coals have maximum hydroaromatic contents as will be seen from the constitutional analysis of coals given in Table 13. With regard to the actual chemical nature of the coal much remains to be done, but infrared spectra indicate weak aromatic C-H vibration, perhaps indicating heavy substitution of aromatic hydrogen.

Previous Work

During 1950-58 sporadic work had been done abroad or in India on hydrogenability or solubility of the Assam coals with a number of catalysts and solvents[12-14]. Several attempts for reduction and recovery of sulphur from coal was also attempted.

TABLE 13 — CONSTITUTIONAL ANALYSIS OF BARAGOLAI 20 FT SEAM COAL (ASSAM)

	DMF ANALYSIS %	% OF TOTAL OXYGEN
1. *Distribution of oxygen*		
O_{COOH}	0·4	3·8
O_{OH}	3·8	35·9
O_{CO}	2·3	21·8
$O_{unaccounted}$	4·07	38·5
		100·0
2. *Distribution of carbon*		
f_{ar}	0·68	
f_{har}	0·28	
f_{CH_3}	0·04	
3. *Distribution of hydrogen*		
$\frac{H_{ar}}{H}$	0·34	
$\frac{H_{har}}{H}$	0·45	
$\frac{H_{CH_3}}{H}$	0·17	
$\frac{H_{OH}}{H}$	0·04	

So far, the primary hydrogenation studies have been made in autoclaves on bench scale. Results indicated that iron catalysts under certain conditions proved to be as effective as costlier catalysts though the concentration required was higher in bench scale autoclave tests. Conversions of 90 per cent or more were obtained at about 200 atm. hot pressure. Significantly, carbon in coal converted to gas in these tests rarely exceeded 5 per cent at maximum hydrogenation temperature of 440°C. and more than 90 per cent of coal (daf) was converted to liquids. The unusual nature of the ash in these coals, apart from sulphur, may have something to do with the ease of hydrogenation, but this remains to be established. Since the revival of interest in Assam coal, more systematic studies have been undertaken for its conversion and catalysts suitable for it. Results of this work are separately presented[15,16].

Results of systematic work with impregnation or precipitation of iron on feed have shown promise and further work in this direction is under way. Work is also being done on characterization of products of different stages of hydrogenation. These data are yet incomplete.

CHAPTER VI

Process Flowsheet

In the process flowsheet adopted in this paper, run-of-mine coal is suitably cleaned of extraneous ash, crushed and dried and is slurried with a suitable vehicle oil. The vehicle oil which is normally a mixture of heavy and middle oils containing hydroaromatic compounds is important. The function of the vehicle oil is to dissolve and de-polymerize the coal and perhaps also act as a reactive hydrogen transfer source. Assam coals are comparatively easily soluble in anthracene oil-type of solvent[17,18].

The catalyst is dispersed by suitably mixing with the coal prior to slurrying. The slurry is pumped along with hydrogen into reaction stalls where primary dissolution and hydrogenation of coals take place. The overhead liquid condensates and split off gases are recovered and the heavy oil residues from the reactor are then separated from unreacted coal mass, catalyst, etc. The residue is stripped off its oil content and sent to the boiler for use as fuel in mixture with middlings. The heavy oil (along with the distillate residues from overhead condensates) is partly recycled for slurrying and the rest is sent to the coker section. The coker oils along with the overhead condensates are distilled into three broad cuts — light, middle and heavy.

In order to maximize middle distillate production, the heavy oil which can be sold as a fuel oil or blended, is hydrocracked for production of lighter and more saturated products along with gas oil from the natural crude.

Middle oil is rich in phenolics and will be treated by suitable techniques for extraction of the desired quantities of phenol and cresols. The middle oil is then hydrotreated in vapour phase by one of the standard techniques and is sent to middle distillates finishing section.

In the hydrotreating section finally all the heteroatoms are removed and adjustments made for flash point and other specifications by removing light ends and separating it into diesel, kerosene and jet fuel fractions. These are the major fuel products and this is the major fuel-producing section.

If it was desired to produce gasoline only, then the entire middle distillate fraction would have been hydrocracked and

reformed for gasoline as in proposed American plants. This step is eliminated in the design pattern adopted for Assam.

The extracted phenolics are fractionated for recovery of pure phenols and cresols. Depending on the requirement, either the entire cresylic fractions and the xylenol fractions can be taken or the cut may be restricted only to cresol isomers and phenols. It is necessary to study carefully the composition of these cuts in pilot plant in order to plan the recovery of the requisite quantities of desired chemicals. Some of the alkyl phenols are of great industrial value even if required in small quantities and could be of considerable importance. The residues and oils from phenol processing sections are returned to the liquid phase hydrogenation system mixed with the vehicle oil.

The light oils from the crude distillation column can be either hydrotreated and stabilized for production of naphtha or treated to remove the remaining traces of hetero atoms to prepare feed stock for chemical production. The balance between naphtha and chemicals produced can be largely controlled according to plan. In the scheme envisaged where refining of syncrude is combined with refining of natural crude, the naphtha from two sections are combined for treatment for production of chemicals.

The naphtha from syncrude is rich in naphthenes and along with its aromatic contents has a considerably greater potential for aromatic recovery than in the case of naphtha from natural crudes. However, the aromatic concentration in Nahorkatiya crudes is fairly high and hence it is worth treating the two naphthas together for aromatic recovery. The recovery of aromatics is done by standard petroleum refining techniques such as by Udex. Nearly one-third of the total naphtha treated is recovered as aromatic chemicals. The bottoms from the naphtha treatment plant have potential for recovery of naphthalene in appreciable quantities though the quantity and the point of cut has to be ascertained from pilot plant studies.

Of the straight naphtha (along with the naphtha from other sources, such as from the cracker, coker and other units), obtained from the syncrude refining, nearly 50 per cent can be recovered as aromatics in BTX range. The potential yield of aromatics up to naphthalene range is possibly of the order of about 63 per cent. Any residues from these fractions can always be returned to the gasoline or naphtha pool. In this scheme, reforming is confined to coal naphtha and the aromatics obtained from petroleum naphtha is from direct extraction of the 45-180/200°C cut. About 160,000 tons will be obtained from coal naphtha as against 64,000 tonnes from petroleum, the major part of the light distillates from petroleum ending up as naphtha for disposal. The stripped BTX is then fractionated to produce benzene, toluene and xylenes. The last named can again be separated into *o-m-p*-xylenes.

The naphtha from the syncrude is reformed where naphthenes are dehydrogenated and there is concurrent dehydrocyclization of the paraffins. The C_6-C_8 naphthenes are converted to the corresponding benzene, toluene, xylene and ethyl benzene.

The hydrogenates also contain cyclopentane and appreciable quantities of cyclohexane, pseudocumenes, ethyl benzene and naphthalenes which can be recovered prior to reforming, if desired. Depending on the severity of reforming, the potential production of aromatics from syn-naphtha can be two to three times as high as a medium mixed base naphthenic crude. In view of the fact that ethyl benzene and butadiene can be available from a syncrude refinery, production of synthetic rubber of SBR type is possible. Other potential aromatics for recovery are pseudocumenes and durene. Other common coal tar polynuclear hydrocarbons such as acenaphthenes, anthracene, phenanthrene, carbazole, pyrene, etc., can also be recovered.

Reforming of naphtha produces substantial amount of hydrogen which is an important credit. The gas stream from coking and residue carbonizer, and if necessary from hydrocrackers, are combined and then fractionated cryogenically for recovery of ethane, ethylene, propane, propylene, butane and butylenes. Ethane and propane are dehydrogenated to increase the yields of ethylene and propylene, liberating hydrogen which is returned to the hydrogenation section. Butane and butylene fractions are processed for production of butadiene.

The remainder of the gas is sent to the reformer section to produce hydrogen. The entire gas stream can be fed into the reformer or if desired a methane fraction from the cryogenic separator could be diverted to natural gas section for further reformation

to hydrogen. The hydrogen from the reforming section is then combined in a hydrogen pool. Thus, hydrogen is produced from three sources: steam reforming of natural gas and off gases, aromatic production unit and dehydrogenation of paraffinic gases.

CHAPTER VII

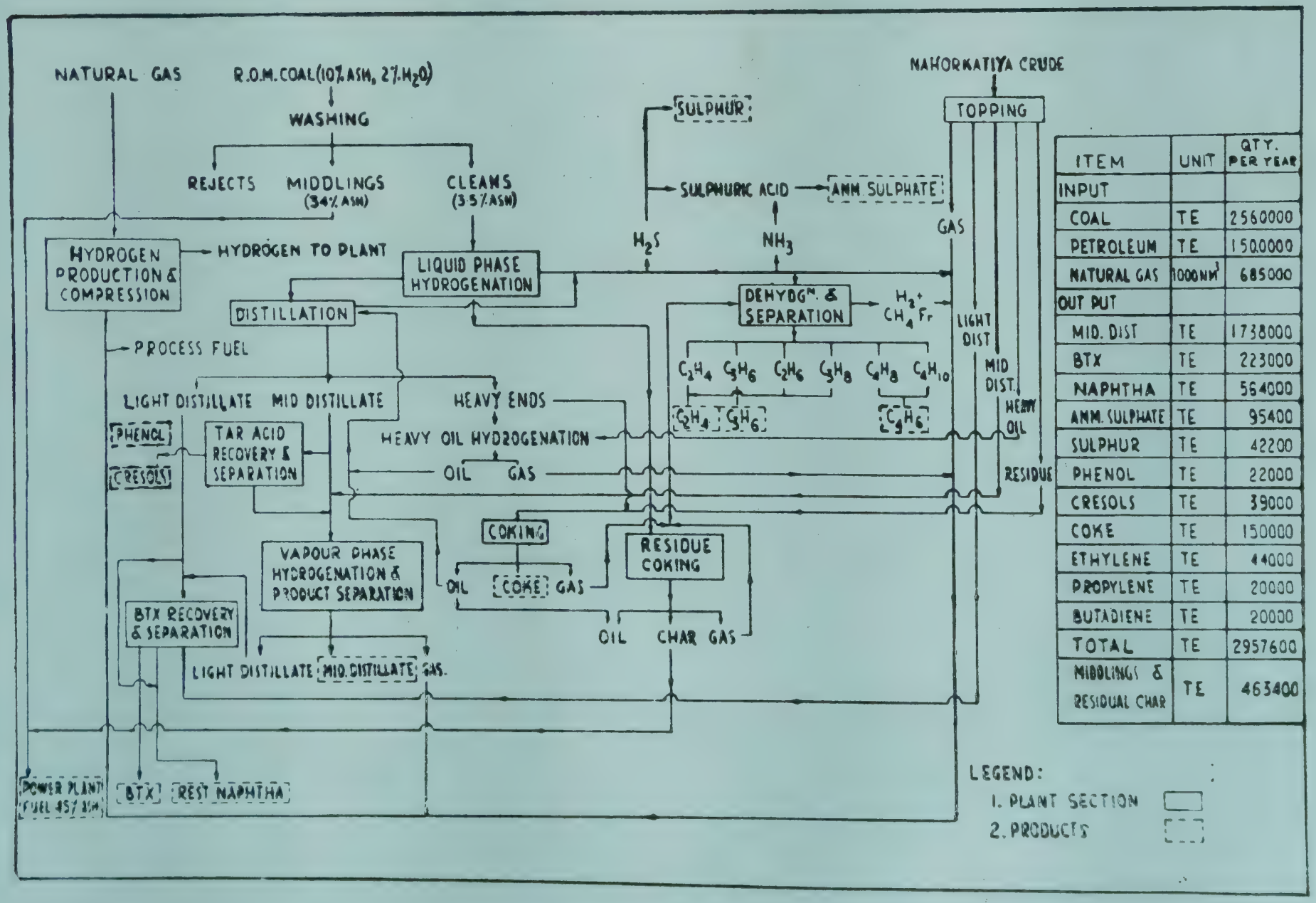
Economics of Proposed Conversion of Assam Coal to Oil and Chemicals

The economics of the project is based on the process steps and flowsheet described earlier and outlined in Fig. 8. The coal (washed) composition is given in Table 14. The basic conversion yields are given in Table 15.

The major objective chosen here is production of middle distillates, i.e. HSD, kerosene and jet fuels and minimizing production of naphtha/gasoline. However, some naphtha will be produced, even after recovery of aromatics, the major part being contributed by the natural crude. This naphtha can either be sold as premium gasoline or for chemical use. Given a market, it is more profitable to produce aromatics than premium gasoline. In this case a market for 0·8 million tons/year of gasoline may not exist. On the other hand,

TABLE 14 — ANALYSIS OF WASHED COAL

	Per cent
Proximate (as received basis)	
Moisture	1·2
Ash	2·9
Volatile matter	43·8
Fixed carbon	52·1
Total sulphur	4·2
Ultimate (daf basis)	
C	80·00
H	5·85
S	8·81
N	1·30
O (by diff.)	9·04
Distribution of sulphur	
S pyrite	0·47
S sulphate	0·04
S organic	3·71



ITEM	UNIT	QTY. PER YEAR
INPUT		
COAL	TE	2560000
PETROLEUM	TE	150000
NATURAL GAS	1000 NM³	685000
OUT PUT		
MID. DIST	TE	1738000
BTX	TE	223000
NAPHTHA	TE	564000
AMM. SULPHATE	TE	95400
SULPHUR	TE	42200
PHENOL	TE	22000
CRESOLS	TE	39000
COKE	TE	150000
ETHYLENE	TE	44000
PROPYLENE	TE	20000
BUTADIENE	TE	20000
TOTAL	TE	2957600
MIDDLINGS & RESIDUAL CHAR	TE	463400

FIG. 8 — INTEGRATED COAL AND OIL REFINERY IN ASSAM

TABLE 15 — CONVERSION YIELDS

	Laboratory data (based on carbon content)	Assumed for feasibility study (based on daf coal)
Conversion to gas and liquid, % daf coal	98	90
Liquid, %	93	70·5
Gas, %	5	18·0
Loss, %	—	1·5

production of aromatics is not only profitable but the residual naphtha will have a ready market either for petrochemicals or for fertilizers. Recovery of aromatics enables the naphtha to be sold comparatively cheap. The requirement of BTX for the IV Plan is more than 200,000 tons and is likely to double in the V Plan.

The costs of plant are based largely on recent American figures suitably modified for Indian conditions and site. The raw coal costs are taken at Rs. 25/- per ton (at pit-head), the equipment for washing and drying are provided. The cost of natural gas is taken at Rs. 9/- per 1000 Nm^3, the price at which it is being currently sold to Assam Electricity Board.

Choice of Size of Unit and Availability of Raw Materials

On the above basis, crediting only the byproducts, i.e. sulphur, ammonia and tar acids, the production costs of middle distillates from a purely coal refinery (unintegrated) of capacities varying from 30,000 to 100,000 BPD are plotted in Fig. 9.

The effect of plant capacity is obvious; the production costs are almost half for the optimum capacity. However, 100,000 BPD of coal-to-oil plant will require 8 million tons of run-of-mine coal per year and nearly 1400 million normal cubic metre of natural gas (4·75 million Nm^3 or 180 million SCF per day). Production of coal in the immediate future on this scale may not be possible. Even more uncertain is the availability of natural gas for a plant of this capacity. The 30,000 BPD coal-to-oil plant will require only 2·5 million tonnes of run-of-mine coal, the natural gas required will be 470 million Nm^3/year or about 1·4 million Nm^3/day (54 million cu. ft/day). It should not be difficult to get this quantity of gas. If this quantity of gas is also not available, then the naphtha produced from the plant itself may be utilized for hydrogen making or hydrogen from steam-oxygen reforming of coal will be used, though both will increase costs.

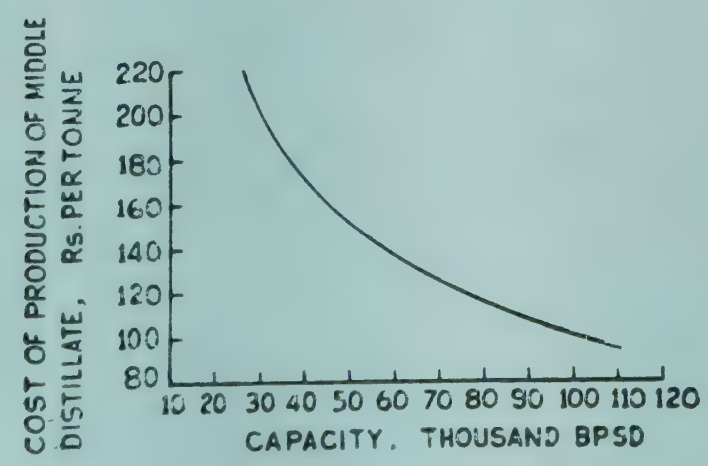


FIG. 9 — EFFECT OF CAPACITY ON PRODUCTION COST OF MIDDLE DISTILLATE [OIL FROM HYDROGENATION OF COAL ONLY WITH 100% RECOVERY OF TAR ACIDS]

The production costs for the smaller capacity are, however, too high. The production costs (with no recovery of chemicals) for a 60,000 BPD plant is in between the two and prima facie appear to be an economic unit for further study. But, in view of the novelty of the process, developments in technology, production potential of coal, natural gas and market for chemicals and byproducts, especially the phenolics and limitations of capital and foreign exchange, it may be prudent to make a beginning with a 30,000 BPD coal-refinery in the first instance, even if the economics appear adverse for the first plant.

A Combined Refinery

An obvious way out of the dilemma and a compromise which also results in several benefits is an integrated coal-to-oil and natural crude refining plant, each contributing approximately 30,000 bbl/day of total oil products. A refinery of this capacity is reasonable and both oil and coal will be available in the quantities required as may be judged from explored and proved reserves and potential of oil, coal and gas. Since Assam crude also will beneficiate by hydrorefining techniques, the integration will be of mutual advantage.

Raw Material Requirements and Product Yields

Table 16 gives the demands of raw material, utility and product yield and pattern of the combined plant.

TABLE 16 — DEMAND OF RAW MATERIAL AND UTILITY AND PRODUCT YIELDS

Raw material requirement	
Run-of-mine coal	$2{\cdot}56 \times 10^6$ Te/yr
Nahorkatiya crude	$1{\cdot}50 \times 10^6$ Te/yr
Natural gas	685×10^6 Nm^3/yr
Utility requirements	
Power	610×10^6 kWh/yr
Raw water	50×10^6 m^3/yr
Catalyst and chemicals	32×10^6 Rs/yr
Product yield	
Middle distillate	1,738,000 Te/yr
Naphtha	564,000 Te/yr
BTX	223,600 Te/yr
Ammonium sulphate	95,400 Te/yr
Sulphur	42,240 Te/yr
Phenol	22,400 Te/yr
Cresols	39,000 Te/yr
Coke	150,000 Te/yr
Ethylene	44,000 Te/yr
Propylene	20,000 Te/yr
Butadiene	20,000 Te/yr
Residual char and washery middlings	463,400 Te/yr

TABLE 17 — UNIT PRICES

Coal	Rs. 25 per tonne
Nahorkatiya crude	Rs. 100 per tonne
Natural gas	Rs. 9 per 1000 Nm^3
Electricity	Rs. 0·05 per kWh
Raw water	Rs. 0·15 per m^3
Labour and supervision	Rs. 250 per man per month
Overhead	100% of labour and supervision
BTX	Rs. 1000 per tonne
Rest naphtha	Rs. 140 per tonne
Ammonium sulphate	Rs. 300 per tonne
Sulphur	Rs. 500 per tonne
Phenol	Rs. 2000 per tonne
Cresols	Rs. 3000 per tonne
Coke	Rs. 500 per tonne
Ethylene	Rs. 800 per tonne
Propylene	Rs. 1500 per tonne
Butadiene	Rs. 2000 per tonne
Residual char and washery middlings (45% ash)	Rs. 15 per tonne

Table 17 gives unit prices which have been assumed for the products ex-refinery. It will be observed that middle distillates constitute 59 per cent and naphtha 19 per cent of the total products, the rest (22 per cent) being chemicals and byproducts, excluding middlings and hydrogenation residues.

The production schedule, however, does not include at present an important by-product, viz. naphthalene for which there is large potential but which is difficult to estimate accurately without further pilot plant tests. Potential recovery may be of the order of 100,000 tonnes/year. Even a partial realization of this potential can substantially affect production costs of energy fuels.

The credits do not also include any recovery of heterocyclics either from the tar or from the liquor as no figures are yet available from bench scale work.

Sulphur recovery will be of the order of 75,000 t/y from the coal refinery, a part (23,000 t/y) of which will be used up for production of ammonium sulphate, the preferred fertilizer for tea plantations. The remainder (42,000 tonnes) will be available for sale to the existing ammonium sulphate plant based on natural gas.

Capital Charges

The basis of calculations of capital charges is given in Table 18. The capital charge calculations adopted here are rather unusual. In calculating interest charges, an average of 6 per cent has been taken, being the average of 9 per cent on two-third loan capital and nil on one-third equity capital. In addition, 10 per cent built-in profit on plant investment (excluding working capital) is added to the capital charges, which is too high for a utility project, but it is included here as a fixed charge on capital as provision for repayment of loan capital and for calculating the selling price of middle distillates. Fig. 10 shows the influence of profit on investment on sale value of middle distillates. The working capital bears a 9 per cent interest and is charged separately.

TABLE 18 — BASIS FOR CALCULATING CAPITAL CHARGES

Depreciation	7·5% on on-site investment 3% on off-site investment
Maintenance	3% on plant investment
Interest	6% on plant investment 9% on working capital
Tax and insurance	2% on plant investment

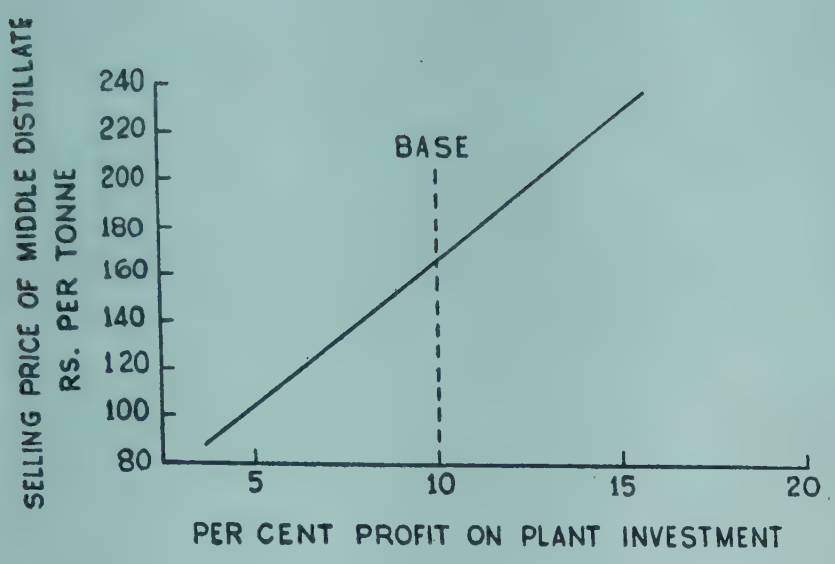


FIG. 10 — EFFECT OF PROFIT ON PLANT INVESTMENT AND SELLING PRICE OF MIDDLE DISTILLATE

The depreciation has been taken at 7·5 per cent on on-site investment and 3 per cent on off-site costs. To these are added tax and insurance charges. In calculating plant costs, the costs of fabrication for the imported quantum, shipping and inland transportation, customs duties and insurance, which together make 1·5 times the U.S. costs are taken. The plant costs included for Indian section are calculated at 20 per cent extra of what it might cost in U.S. Of course, plant costs in both sections are taken as assembled and commissioned.

The operating charges include raw material, catalysts, chemicals, utilities, wages and supervision, overheads and maintenance at 3 per cent on plant costs and are given in Table 18.

The capital investment for mining is not included and is likely to be of the order of Rs. 80-100 per t/y coal produced depending on whether open-cast or underground mining is involved. The coal costs are taken at cost-basis as a part of the project. Coal preparation and handling costs are included, but no transportation costs from mine head are included. The oil and gas will be delivered to the refinery by pipelines and the raw material costs are inclusive of these charges.

As regards electricity, delivery at 5 p/kWh has been taken, but no separate capital investment is allowed. A power station will be essential as upper Assam has no power surplus and in such a case middlings and hydrogenation residues must be utilized at site. On the basis of the present scheme, the project will require a 80 MW power station with necessary standby, but in view of other industries which must follow, a larger unit will be required.

The additional investments for development of coal and power will be about Rs. 35·4 crores.

Production Costs

The selling price of middle distillates is calculated by deducting the total annual credits for BTX, naphtha, ammonium sulphate, sulphur, phenols, cresols, petroleum coke, ethylene, propylene, butadiene as well as residual char and middlings, etc., from the total annual debits on account of capital and operating charges and dividing the sum by the expected annual production of middle distillates.

The economic summary is given in Table 19, including investment break-up in foreign and Indian currencies. The foreign exchange content is approximately Rs. 113·5 crores. The corresponding import value of the middle distillates will be about Rs. 35 crores/yr.

The sale value of the middle distillates on the basis of these estimates amounts to Rs. 166 per tonne as against estimated ex-refinery price of HSD and other middle distillates of Rs. 180-200 per tonne. Against this estimated cost, effect of sale value of middle distillates with variation in coal prices are shown in Fig. 5. The variation in selling cost of middle distillates with change in value of natural gas is shown in Fig. 11.

The sale value of middle distillates against variation in profit on plant investment is indicated in Fig. 10. It may be noted that 10 per cent of profit on plant investment is already included in arriving at the sale value of middle distillates. This is in addition to 9 per cent interest paid on loan capital and 9 per cent on working capital. Taking one-third as equity capital,

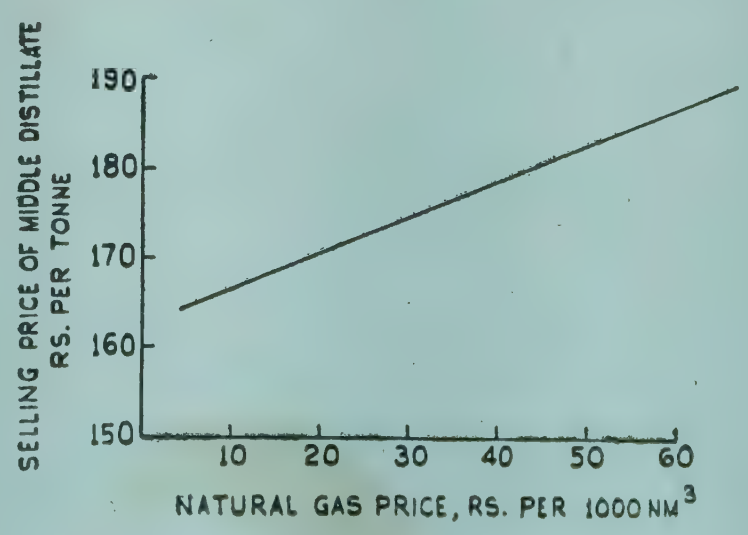


FIG. 11 — EFFECT OF NATURAL GAS PRICE ON SELLING PRICE OF MIDDLE DISTILLATE

TABLE 19 — ECONOMIC SUMMARY

Plant capacity	30,000 BPSD oil from coal 30,000 BPSD oil from NHK crude	
Yield of middle distillate		1,738,000 Te/yr
Plant investment	On-site:	Rs. 1,776·54 million
	Off-site:	Rs. 406·00 million
	Total	Rs. 2,182·54 million
Working capital		Rs. 138 million
Annual operating expenses		Rupees, million
Run-of-mine coal		64·00
Nahorkatiya crude		150·00
Natural gas		6·16
Sub-total for raw material		220·16
Power		30·50
Raw water		7·50
Catalyst and chemicals		32·00
Sub-total for utilities		70·00
Labour and supervision		37·00
Overhead		37·00
Sub-total for wages/salaries		74·00
Depreciation		145·42
Maintenance		65·47
Interest		143·37
Tax and insurance		43·65
Sub-total for capital charges		397·91
Ammonium sulphate		28·62
Sulphur		21·12
Phenol		44·80
Cresols		117·00
Coke		75·00
Ethylene		35·20
Propylene		30·00
Butadiene		40·00
Residual char and middling		6·95
Total annual credit		691·25
Net annual expenses		70·82
10% profit on plant investment		218·25
	Total	289·07
Selling price of middle distillate		Rs. 166 per tonne

Investment Break up

1. *On-site investment*	Rs. 1,776·54	million
Foreign	Rs. 1,135·08	million (64%)
Indian	Rs. 641·46	million (36%)
2. *Off-site investment*	Rs. 406·00	million
Foreign	nil	

Total Plant Investment Rs. 2,182·54 Million

Foreign	Rs. 1,135·08	million (52%)
Indian	Rs. 1,047·46	million (48%)

the profit is fixed at 33 per cent in fixing selling price. This is too high a return for an utility concern. A total return at 16 per cent (10+6 per cent) on plant investment or 8 per cent after taxes has been allowed. This is in contrast with 4-7 per cent ROI allowed for American projects.

Marketing of Products

As regards possibility of markets for the byproducts, the total annual credit of which (excluding naphthalene) comes to Rs. 612 millions, one has to remember that the refinery cannot perhaps be built before the V Plan and will come into commission towards the end of the Plan. Therefore, markets for all the products have to be taken on a projected basis. Further, for utilization of the aromatic and olefines, corresponding consumer facilities, i.e. other petro-chemical plants will have to be built, the planning for which must also be simultaneously undertaken. It is, however, possible to export the aromatics and phenols to be used elsewhere.

Delay in setting up of such plants will involve marketing total lighter fractions as naphtha/gasoline and the olefinic precursors will be used up in hydrogen production.

Of the aromatic chemicals amounting to nearly 223,000 tonnes per year, the most problematic outlet will be for toluene (68,000 tonnes/year). The current demand for toluene will be only of the order of 6000 t/y for the IV Plan. Uses must be found either by conversion to benzene or other chemicals, e.g. caprolactum, benzoic acid, benzaldehyde, etc., or alternatively the whole of toluene fractionated may be converted to benzene (synthesis grade). If mother gasoline has market, then part of the toluene can be blended back to the naphtha. With the expected increase in production of synthetic rubber, polystyrene, phenols, cyclohexanes, maleic anhydride, solvents, pesticides, etc., there will be sufficient offtake for the aromatics, especially for benzene, by the end of 1970s. An increase of twofolds over expected consumption in the IV Plan (170,000 tons benzene/yr) is not an unreasonable projection, but market for toluene will be definitely limited. The project will produce only 45,000 tons of benzene and there is, therefore, definite scope of hydro-dealkylation of the entire quantity of toluene to

benzene. This is easily done in the present complex. Failing this, there will be no alternative but blending it back to gasoline. Since this will be a premium gasoline and part of it could be reconstituted into blends for producing aviation fuels (some quantity of which is still imported), the credits may not be substantially affected. Since the production pattern of aromatics may be of the order of 1 : 1·5 : 2·5 of benzene, toluene and xylene, the last named will be produced in major quantities (112,000 tonnes). While *o*- and *p*-xylenes have established demands for phthalics, there may be some problem for marketing *m*-xylenes. However, isomerization is a likely solution unless production of isophthalic acid is planned. Export of xylenes is a definite possibility, but dealkylation of a part, etc., to benzene (along with toluene) may also be planned.

As regards the rest, neither ammonium sulphate nor sulphur, nor petroleum coke will have any problem of marketing. The expected shortage of petroleum coke during the Plan is of the order of 60,000 tonnes per year and since the aluminium industry will expand, there will be no difficulty of its disposal.

As regards ethylene, propylene and butadiene, it is expected that their utilization will be done in a petro-chemical plant to be located along side.

The final product pattern will, of course, depend on the market and plans for other chemicals. Basically, production of ethylene polymers, ethyl alcohol, ethylene glycols, ethylene dichloride, vinyl chloride, isoprene, acrylates, detergents, etc., can be envisaged. Also, the route for vinyls and acrylics have now veered round to ethylene and propylene instead of customary acetylene. Any such production will be well within the scope of the coal-petroleum refinery. Similarly, intermediates for the rubbers will also be available.

The char and washery middlings will have to be utilized on the spot for generation of power and it will be necessary to build a power plant, as the availability of power, thermal or hydel, in Assam, is strictly limited.

Some sulphur may be available from the power station flue gases, but this cannot be computed at this stage. No possibility has been explored for recovery of rare metals, especially germanium, which is high in Assam coals. The available data on composition of ash are presented in Table 5 and Appendices 4, 5 (*see FRI News*, June-Sept. 1970, p. 66) and 10. Recovery of rare metal, in due course, may be kept in view. The middlings and hydrogenation residues will be combined with raw coal for a larger power plant for future requirements. The hydrogenation residue can also be profitably used in road construction[19].

CHAPTER VIII

Conclusion

This preliminary feasibility study indicates the possibility of economic production of oil from coal in a combined refinery based on Assam coals with current known technology and the process will fulfil the need for a substantial part of a specific and strategic energy fuel and for intermediate chemicals for a petro-chemical industry which must come in Assam one day. The project will also be a major step for industrialization of Assam based on raw material resources of the State. Basically, the product transhipment will be more economic than shipment of crudes and since a major part of the products will be high cost chemicals, the economics of location of the plant in upper Assam is all the more justified.

Even more important is that successful implementation of such a plant which will enable a very large reserve of the unique coals of Assam (ultimately both in upper and lower Assam) to be used for meeting the vital energy needs of the country as a whole. In terms of *in situ* reserves, coal resources of Assam represent a resource of nearly 750 million tonnes of oil and chemical products, as against proved reserves of perhaps not more than 100 million tons of natural crude. [Of course, this is based on assumption that the coal reserves can be economically mined and are not merely geological reserves.] This alone may be a justification for further pursuance of the project.

Exploration and Research

During the next 10 years, it is almost certain that several major coal-to-oil plants will come into operation in the USA. They will naturally be based on different techniques and will have different product patterns. While the experience and technology developed in the USA will be useful,

we in India must develop our own technology and utilize our unique resources for our own specific requirements, which are rather different, raw material-wise and product pattern-wise, from other countries. This calls for painstaking exploration, research and development and investment in pilot plant research. This preliminary feasibility study does indicate the justification of investment in research in this as a 'National Project', perhaps in collaboration with competent engineering firms abroad who have contributed to development of coal hydrogenation.

While detailed exploration of deposits, especially in north Assam, must immediately be taken up, without which no firm project can be prepared, technological research as well as fundamental studies must be undertaken on an adequate scale at the National Laboratories. This is a national project justifying advance investment.

A beginning has been made at the CFRI, but plant and equipment are not sufficient for the scale on which such R & D work must be done if one expects to get reasonable information to plan production on a firm basis. There are far too many gaps and assumptions in our study (and of others). They have to be filled. All these justify further investment perhaps even without any hope of immediate gains.

With the help of the USA, the CFRI has been able to secure the service of Dr E. E. Donath, one of the greatest experts in the field of coal hydrogenation, who will be with us in helping us to elaborate this feasibility study and in planning out our research projects.

It will be necessary to set up at least a one ton/hour continuous coal hydrogenation plant complete in all respects so that products are sufficient for study for various processes involved and for firm projection of quality of products and yields.

Finally, it would appear that at current prices and even with the present stage of technology and knowledge, a coal-to-oil refinery can be feasible provided chemicals and byproducts are profitably disposed of. The byproduct credits amount to Rs. 266 per ton of middle distillate produced and largely offset the heavy capital charges and raw material costs. The economics are better for a combined coal-to-oil and natural crude refinery with advantage to both the sections. We may tentatively conclude that:

1. The economics of a coal-to-oil plant based on coal only depends on (i) capital charges and scale, (ii) cost of coal, (iii) cost of hydrogen, (iv) cost of catalysts, and finally (v) on the extent and sale value of the chemicals and byproducts.

2. Under conditions assumed for Assam, with coal at Rs. 25/- per ton, natural gas at Rs. 9/- per MNm^3, production of oil from coal alone can be competitive with import costs of middle distillates only on a scale of 100,000 BPD, with partial chemical recovery. This will require 8 million tones/year of coal, 1500 $MMNm^3$/yr natural gas and produce 3·3 MM tons/yr of middle distillates.

3. The smallest unit, 30,000 BPD based on coal only, may not be fully competitive unless a substantial part is converted to chemical products. This is largely due to higher per ton capital investment.

4. The ideal combination, which calls for reasonable production of coal and availability

TABLE 20 — TOTAL INVESTMENT FOR THE PROJECT

Capital investment for the erected plant	Rs. 218,25,40,000
Capitalization of interest @ 9% p.a. during the 5 years' construction period (Table 2)	Rs. 67,19,74,380
Working capital (Table 3)	Rs. 13,81,60,000
Total	Rs. 299,26,74,380

TABLE 21 — CAPITALIZATION OF INTEREST DURING CONSTRUCTION PERIOD

Capital investment for the erected plant	Rs. 218,25,40,000
Auxilliary installations during 5 years' construction period	Rs. 8,00,00,000
Total capital during construction	Rs. 226,25,40,000

Year	Per cent total capital	Amount Rs.	Interest @ 9% p.a. Rs.
1st	20	45,25,08,000	4,07,25,720
2nd	50	113,12,70,000	10,18,14,300
3rd	70	158,37,78,000	14,25,40,020
4th	90	203,62,86,000	18,32,65,740
5th	100	226,25,40,000	20,36,28,600
		Total	67,19,74,380

TABLE 22 — DETAILS OF WORKING CAPITAL

One month's reserve of coal	Rs.	58,20,000
One month's reserve of crude	Rs.	1,36,50,000
One month's reserve of natural gas	Rs.	5,60,000
Three months' wages	Rs.	90,00,000
5% on plant investment	Rs.	10,91,30,000
Total	Rs.	13,81,60,000

TABLE 23 — PROFIT ON EQUITY CAPITAL

1. Equity to loan capital ratio	1 : 2		
Equity capital	Rs.	9975·6	lakhs
Loan capital	Rs.	19951·2	,,
2. Total annual credit*	Rs.	9803·2	,,
3. Total annual debit in the 1st year			
Annual debit without interest	Rs.	6187·0	,,
Interest on loan capital @ 9% p.a. (Rs. 19951·2 lakhs)	Rs.	1795·6	,,
	Rs.	7982·6	,,
4. Profit on equity capital in the 1st year (2)-(3)	Rs.	1820·6	,,
5. Total annual debit in the 2nd year			
Annual debit without interest	Rs.	6187·0	,,
Interest on loan capital @ 9% p.a. (Rs. 17999·7 lakhs)	Rs.	1620·0	,,
	Rs.	7807·0	,,
6. Profit on equity capital in the 2nd year (2)-(5)	Rs.	1996·2	,,
and so on....			

*Sum of credit from byproducts and credit from sale of middle distillate at Rs. 166 per tonne calculated on the basis of 10 per cent return on plant investment.

of natural gas and at the same time reduces capital investment per ton of products due to scale effect, is a 60,000 BPD integrated plant with apporoximately equal liquid product yields from natural crude. Additional advantages are: (i) lower hydrogen demand from outside source, (ii) improvement in quality and quantity of saleable energy fuels from Assam crude, (iii) a better product pattern and quality, (iv) lower off-site and storage costs, (v) reduction of percentage in foreign exchange in relation to capital investment, (vi) lower operation costs, and (vii) greater flexibility of blending of products to meet market specifications. The disadvantage is higher production of naphtha contributed by natural crude. Raw materials required are 2·6 million tons of raw coal, 1·5 million tons of natural crude, 2·03 MMNm³/day (80 MM cu.ft/day) of natural gas which will produce 1·74 MMt/yr middle distillates, 0·56 MMt/yr naphtha, 0·223 MMt/yr BTX, 150,000 t/yr ashless coke, 61,400 t/yr of phenol and cresols, 34,000 t/yr of olefines, 95,400 tons of ammonium sulphate, 42,240 tons of sulphur and 463,400 tons/yr of middlings and hydrogenation residue as boiler fuel, valued at Rs. 980 million/yr of which chemical and byproducts (excluding naphtha) constitute Rs. 612 mill./yr.

5. Under the conditions assumed the return on equity capital investment has been taken at 33 per cent (before corporate tax) and total return at 16 per cent (before taxes) on plant investment, i.e. equivalent to an ROI 8·8 per cent after taxes on full equity compared to American estimates of 4-5 per cent ROI on coal-to-oil plants for all gasoline production and up to 6 per cent for two-third fuel and one-third for chemical plants.

6. With two-third as loan capital having 9 per cent interest and one-third equity and at an average sale value of middle distillates at Rs. 166/ton (compared to Rs. 180-200/ton of current sale value), the total loan capital will be repaid in 8 years. The calculations are given in Tables 20-24.

7. The difference in sale value (ex-plant) of middle distillates and current market prices, Rs. 34/ton, enable a profit of 6 per cent (before taxes) to be made on equity, even when full provision for repayment of loan capital is made from built-in profits on total investment.

8. The preliminary feasibility study justify substantial investments in (i) exploration, (ii) R & D, (iii) a more detailed techno-economic study (now in progress).

9. The plant investment for the combined refinery (both on- and off-site) will be Rs. 2200 million of which Rs 1135 million will be foreign exchange (the import value for middle distillates will be at least Rs. 350 million per year).

10. Additional investments for coal and power development will be about Rs. 350-400 millions.

The energy resources, liquid, solid or gaseous, belong to the nation. Their combined development in an integrated plant will depend on the wisdom of our leaders and planners. The opportunity exists.

A. Lahiri & D. K. Mukherjee

TABLE 24 — PROFITABILITY ANALYSIS AND PAY-OUT SCHEDULE FOR LOAN CAPITAL

(Loan to equity capital ratio, 2 : 1; total capital investment, Rs. 299,26,74,380; Rs. in lakhs)

Year after full production	Equity capital	Loan capital	Profit on equity	Depreciation fund	Interest @9% on dep. fund	Total profit	Total profit % equity capital	Corporate tax 45% on total profit from 6th year	Net profit	Net profit for distribution after tax, % equity capital	Remarks
	9975·6	19951·2	—	—	—	—	—	—	—	—	
1st	9975·6	17999·7	1820·6	1454·2	130·9	1951·5	19·6	—	—	—	
2nd	9975·6	15741·7	1996·2	2908·4	261·8	2258·0	22·6	—	—	—	
3rd	9975·6	13149·5	2199·5	4362·6	392·7	2592·2	25·8	—	—	—	
4th	9975·6	10193·2	2432·7	5816·8	523·6	2956·3	29·6	—	—	—	
5th	9975·6	6839·9	2698·8	7271·0	654·5	3353·3	33·6	—	—	—	
				End of Tax Holiday							
6th	9975·6	4757·6	3000·6	8725·2	785·4	3786·9	38·0	1703·7	2082·3	—	
7th	9975·6	2500·2	3188·0	10179·4	916·3	4104·3	41·2	1846·9	2257·4	—	
8th	9975·6	59·1	3391·2	11633·6	1047·2	4438·4	44·5	1997·3	2441·1	—	
9th	9975·6	nil	3610·9	13087·8	1178·1	4789·0	48·1	2155·1	2633·9	25·8	Rs. 2574·8 lakhs available for distribution
10th	9975·6	nil	3616·2	14542·0	1309·0	4925·2	49·4	2216·3	2708·9	27·2	

References

10. Conn, A. L. & Corns, J. B., American Oil Company, Proj. No. 6120, Dec. 8, 1967.
11. Rao, H. S., Murthy, G. S., Gupta, P. L., Subbaratnam, N. R. & Lahiri, A., *J. sci. industr. Res.*, **18B** (1959), 376.
12. Basak, N. G., Bose, S. K., Ghosh, S. & Lahiri, A., *J. sci. industr. Res.*, **14B** (1955), 284.
13. Bose, S. K., Basak, N. G. & Lahiri, A., *J. sci. industr. Res.*, **18B** (1959), 255.
14. Basu, A. N. & Glenn, R. A., *J. sci. industr. Res.*, **9B** (1950), 64.
15. Mukherjee, D. K., Sama, J. K., Choudhury, P. B. & Lahiri, A., *Hydrogenation of Coal with Iron Catalyst: Parts I & II*, paper presented at the Symposium on Chemicals and Oils from Coal, CFRI, 1969.
16. Mukherjee, D. K., Sama, J. K., Mukherjee, S. K., Choudhury, P. B. & Lahiri, A., *Effect of Reaction Variables on Hydrogenation of Baragolai (Assam) Coal*, paper presented at the Symposium on Chemicals and Oils from Coal, CFRI, 1969.
17. Lahiri, A. & Basu, A. N., *Indian Patent* 49729, 1953.
18. Srinivasan, S. R. *et al.*, *J. sci. industr. Res.*, **19B** (1960), 10.
19. Calkins, J. M. & Silver, H. F., *A Study of the Hydrogenation of a Wyoming Coal to Produce a Bituminous Cement for Road Construction*, paper presented at the Symposium on Fossil Hydrocarbon and Mineral Processing: Part III, Utah, USA, May 1967.

APPENDICES

APPENDIX 7 — PROPERTIES OF NAHORKATIYA CRUDE

1. Specific gravity at 60°F/60°F	0·8574	6. Sulphur %	0·17
2. Water V.%	0·06	7. Ash %	0·024
3. Viscosity, cs/100°F	4·91	8. Sediment %	0·02
4. Pour point °F	87	9. Gross calorific value Btu/lb.	19206
5. Asphaltenes %	0·033		

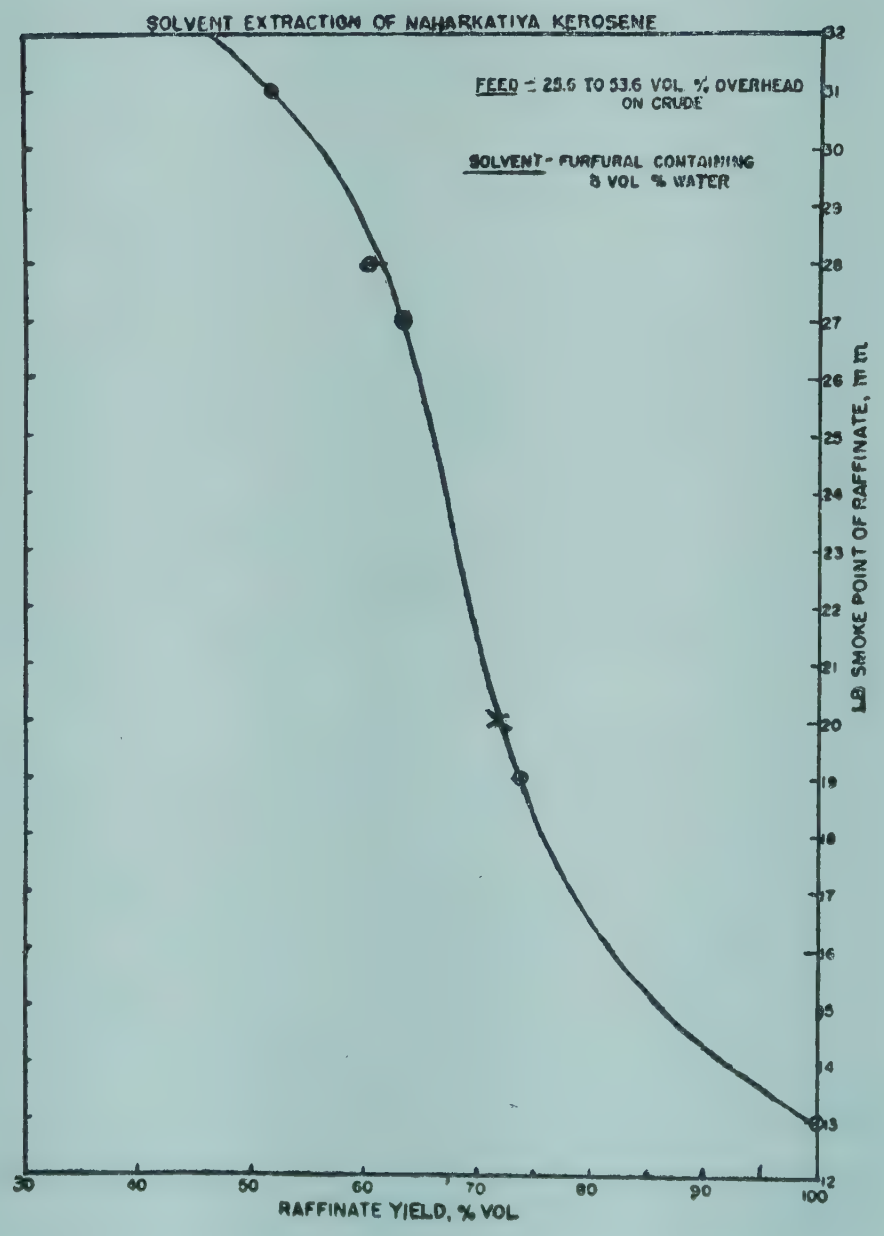
Ref.: Ishwar Chandra *et al.*, *J. sci. industr. Res.*, **18B** (1959), 285.

APPENDIX 8 — HYDROCARBON TYPE DISTRIBUTION OF NAHORKATIYA CRUDE

Hydrocarbon type		Temperature range of the 10 per cent volume cuts, °C								
		42 to 109·2	109·2 to 145·2	145·2 to 185·2	185·2 to 241·2	241·2 to 283·9	283·9 to 338	338 to 398	398 to 443	443 to 478
Aromatics, % V. (by specific dispersion)		25·6	29·4	39·6	—	—	—	—	—	—
Naphthenes, % V. (by refractivity intercept)		18·7	32·8	24·3	—	—	—	—	—	—
Paraffins, % V. (by refractivity intercept)		53·3	34·2	36·7	—	—	—	—	—	—
Structural analysis (by n.d.p. method)	C_A%	—	—	—	26·5	28·8	30·9	29·3	23·5	21·2
	C_N%	—	—	—	25·2	27·7	20·7	16·5	13·5	13·2
	C_P%	—	—	—	51·7	56·5	51·6	45·8	37·0	34·4
	C_P%	—	—	—	48·3	43·5	48·4	54·2	63·0	65·9
	R_A	—	—	—	0·52	0·65	0·80	0·95	1·00	1·08
	R_N	—	—	—	0·52	0·65	0·67	0·73	0·79	0·95
	R_T	—	—	—	1·04	1·30	1·47	1·68	1·79	2·03

Ref.: Ishwar Chandra *et al.*, *J. sci. industr. Res.*, **188** (1959), 335.

APPENDIX 9



APPENDIX 10 — COMPOSITION OF ASH FROM SOME ASSAM COALS

Sl No.	Seam	Colliery	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	TiO_2	CaO	MgO	SO_3	Alk. (by diff.)	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	5 ft.	Baragolai	51·14	17·00	21·87	0·10	0·69	2·75	2·17	Trace	4·28	100·00
2	20 ft.	do	38·86	23·17	29·09	0·06	1·35	1·36	1·58	2·56	1·97	100·00
3	20 ft.	do	40·50	23·21	26·80	0·15	0·89	1·32	1·35	2·11	3·67	100·00
4	20 ft.	Namdung	46·3	17·2	14·7	0·1	0·7	7·1	4·1	8·9	0·9	100·00
5	20 ft.	Tipong	36·5	15·9	37·1	0·2	0·6	1·0	1·7	3·3	3·7	100·00
6	New seam	do	54·53	10·19	25·74	0·14	Trace	2·24	1·98	4·95	0·23	100·00
7	do	Ledo	50·2	16·0	28·1	0·1	0·9	1·0	0·9	0·5	2·3	100·00
8	Top coal	Tipong	39·19	8·00	36·39	0·08	0·85	2·76	2·69	6·26	3·78	100·00
9	do	do	36·77	11·74	36·69	0·11	0·61	3·15	3·02	5·11	2·80	100·00
10	do	Namdung	58·8	19·3	15·3	Trace	1·0	1·1	1·3	0·7	2·5	100·00
11	do	Tipong	47·8	17·0	21·1	0·3	1·1	1·3	1·5	3·0	6·9	100·00
12	Bottom coal	do	45·97	12·79	23·83	0·05	1·17	3·38	2·02	2·90	2·19	100·00
13	do	Baragolai	57·3	20·1	14·2	0·1	1·2	1·1	1·3	0·7	4·0	100·00
14	do	do	60·6	22·0	10·0	0·2	1·2	0·7	1·5	0·4	3·5	100·00
15	do	Namdung	55·5	18·6	16·5	0·1	1·0	1·3	1·6	1·2	4·2	100·00
16	do	do	55·5	19·9	17·4	0·1	1·0	0·8	1·0	1·5	2·8	100·00
17	60 ft.	do	59·8	21·2	13·0	0·1	1·0	0·9	0·8	0·3	2·9	100·00
18	60 ft.	Ledo	63·7	20·2	9·9	0·1	1·0	1·1	0·7	0·5	2·8	100·00
19	60 ft.	do	63·9	17·4	12·7	Trace	1·0	0·5	0·7	0·8	3·0	100·00
20	60 ft.	Tipong	58·7	24·5	10·2	0·1	1·2	0·5	1·3	0·9	2·6	100·00
21	60 ft.	do	55·1	17·1	18·2	0·1	0·8	1·7	1·7	1·4	3·9	100·00
22	60 ft.	Baragolai	57·8	19·0	11·6	0·1	1·2	1·6	1·4	1·1	6·2	100·00

...FIELD

Particulars	...s				C.I.	GK LTC assay at 600°C (per ton of dry coal)		
	Moist %	N %	Sorg. %	O (by diff.) %		Tar gal.	Gas cu.ft	Cok type
8 ft seam	3·0 to 3·5	1·5 to 1·7	3·7 to 3·8	10·9 to 12·1	17 to 18	32·9	4,000	F
5 ft seam	2·1 to 2·7	1·3 to 1·6	3·3 to 4·5	8·8 to 9·3	16 to 24	32·7 to 43·0	3,500 to 4,100	F to G_1
Thin seam	2·4 to 2·8	1·4 to 1·6	5·7 to 6·8	8·1 to 8·5	28 to 36	30·6 to 34·6	3,400 to 4,000	F to G
20 ft seam								
(i) Seam overall	2·1 to 2·6							
(ii) ROM	2·3 to 2·5	1·3 to 1·5	3·4 to 6·0	7·7 to 9·3	20 to 33	31·0 to 45·6	3,400 to 4,300	G to G_3
New seam	2·2 to 4·0	1·4 to 1·5	1·6 to 4·3	10·0 to 11·0	14 to 23	29·8 to 40·4	3,900 to 4,000	G to G_1
Thick Seam								
(A) *Top Coal*								
(i) Seam overall	2·3 to 2·5	1·3 to 1·4	1·7 to 2·7	9·2 to 9·9	15 to 27	35·0 to 43·0	3,500 to 4,200	F to G_1
(ii) ROM	1·7 to 2·8							
(B) *Bottom Coal*								
(i) Seam overall	2·0 to 2·6	1·3 to 1·5	1·7 to 2·7	9·2 to 9·9	15 to 27	35·0 to 43·0	3,500 to 4,200	F to G_1
(ii) ROM	2·1 to 2·2	—	—	—	—	—	—	—

Spotlight

ON SCIENTIFIC ACTIVITIES

South Karanpura Coalfield— An Appraisal*

In the Upper Damodar Valley region there is an area of about 1400 sq. km. of Gondwana formation which is divided by a strip of Talchir and Archaean rocks into two unequal portions of about 1200 and 200 sq. km. The larger one to the north and north-west is called the North Karanpura coalfield and the smaller one to the south-east, demarcated between the latitudes 23°38′5″ and 23°43′N and longitudes 85°8′50″ and 85°30′40″E is called the South Karanpura coalfield from the name of the Pargana in which the two portions mostly lie.

Exploration studies by various drilling organization proved that only Barakar series and Karharbari stage are the two coal-bearing horizons in the field.

Physical and chemical survey of the borehole cores by the Coal Survey Laboratory (CFRI), Ranchi, has revealed the occurrence of forty-one seams which could be classified into six groups of alternate good and inferior varieties, starting with inferior coals.

The grouping of the seams are as follows:

Gr. 1 Saunda, Upper Sayal (CFRI discovery), Sayal, Upper Balkudra and Balkudra

Gr. 2 Kurse, Upper Nakari, Lower Nakari and Upper Semana

Gr. 3 Lower Semana, Semana 'A' to Semana 'B', Hathidari, Bansgarha, Bansgarha 'A' and Bansgarha 'B'

Gr. 4 Bansgarha 'C', Bansgarha 'D'. Sirka, Sirka 'A', Argada and Argada 'A'

Gr. 5 Argada 'B' and Argada 'R'

Gr. 6 Argada 'S' to Argada 'T'

Coals from seams Saunda to Balkudra are inferior with comparatively high ash (19-37 per cent ex. dirt bands and 24-51 per cent including dirt bands, both on air dried basis). Those from Kurse to Upper Semana are comparatively good in respect of ash percentage (13-24 and 17-45 respectively as above). Seams from Lower Semana to Bansgarha contain again bad quality coal (air-dried ash per cent varying from 15 to 30 on ex. band basis and 18 to 45 on including band basis). Seams from Bansgarha 'C' to Argada 'A' yield better quality coals while those from Argada 'B' to Argada 'R' again a poor quality. In these cases the corresponding ash percentages vary between 13 and 33 (ex. bands) and 17 and 40 (incl. bands) for the former and 19-35 and 23-50 for the latter.

Approximate proved coal reserve in South Karanpura coalfield may be estimated at present to be of the order of 1000 million tonnes (gross *in situ* reserve).

There are at present 16 collieries (of which 6 are in the public sector) producing approximately 4 million tonnes of coal annually.

*Based on a paper " An Appraisal of the South Karanpura Coalfield ", by A. K. Datta & K. C. Lahiri.

Upgrading of Small Coal from Bisrampur Colliery

The present production of Bisrampur colliery of the National Coal Development Corporation (NCDC) is about 9 lakh tonnes per year which is expected to reach 1·85 million tonnes in the near future. The run of mine coal is size separated into three fractions: +25, 25-6 and −6 mm. While the first two fractions are directly consumed in locomotives and power generation, the small fraction (present production, 1 lakh tonnes) finds no outlet because of its high ash content (20-25 per cent). The disposal of this fraction poses a serious problem in addition to considerable loss of combustible matter. On a request from NCDC, the Central Fuel Research Institute (CFRI), Dhanbad, undertook investigations

on the upgrading of coal fines (below 6 mm.) of the Bisrampur colliery.

The Institute carried out screening and float and sink tests and explored the applicability of various techniques for upgrading including (i) selective and wet screening, (ii) separation in hydrocyclone and concentrating table, and (iii) dewatering of products by drainage, filtration and oleoflotation process.

The results of laboratory screening and float and sink tests have revealed that the associated dirt is of extraneous nature which is concentrated in the fraction below 1 mm. The problem of upgrading these fines is, therefore, mainly a problem of size separation.

The tests point to the conclusion that the most attractive solution is the wet screening of the small coal in sieve-bend at about 1 mm. followed by vibrating screen, and beneficiation of the slurry below 1 mm. (where necessary) by hydrocyclone. By this simple process of upgrading, about 85-90 per cent of the raw coal can be recovered with an ash content of about 17 per cent from a level of about 22 per cent.

The adhered moisture content of the sieve-bend and dewatering screen overflow (plus 1 mm.) was about 20 per cent but there is scope for reducing the moisture by using a high frequency vibrating screen. Experiments in a 150 mm. diam. drainage column showed that the surface moisture could be brought down to about 8 per cent in about 5-6 hr.

Filtration of the upgraded slurry (—1 mm.) is beset with difficulties. Instead, provision for a number of settling tanks for receiving and settling and sun-drying of slurry appears to be attractive.

However, on mixing the partially dewatered 6-1 mm. small coal and —1 mm. cleaned slurry cake with the raw 25-6 mm. size coal, it is expected that the free moisture content of the combined product would hardly exceed 6-7 per cent, which should be acceptable to power plants.

Extraction and Dealkylation of Phenols from Coal-Oils*

During carbonization and hydrogenation of coal, phenols constitute an important product component, proper recovery and utilization of which is one of the key factors in their economics. Extraction of phenols from the phenolic oil fractions has attracted the attention of researchers the world over. Except for an experimental dual solvent extraction pilot plant using aqueous methanol and hexane by ALCOA in Texas, USA, attempts at substitution of caustic soda as an extractant has not yet met with any significant success, in spite of some major disadvantages of caustic soda, particularly where high boiling phenols are involved. Economic factors have been the main hindrance. Only a cheap solvent capable of preferential extraction is called for. The tar and byproducts laboratory of the CFRI has succeeded in developing such a solvent, indeed a throw away solvent, the very dilute aqueous ammonia which, in three stages, can extract all the phenol, most of the cresols and a major portion of the xylenols. Experimental runs in the laboratory with both low temperature carbonization tar-oil fractions and with oils obtained from slurry phase coal hydrogenation have proved the solvent to be quite feasible.

The other major hindrance in phenol utilization is that in such coal-processing techniques, highly alkylated phenols are produced. Dealkylation of phenols involves a problem not met with in dealkylation of hydrocarbons for which several excellent processes are available, viz. that the hydroxyl group is removed more easily than the alkyl. Since thermodynamically it is so, the solution must be found in the kinetics of the process, i.e. finding a catalyst which will accelerate dealkylation to a much greater degree than dehydroxylation, thus effectively suppressing the latter.

After a survey of catalysts, the CFRI has developed a catalyst which almost entirely suppressed dehydroxylation, i.e. at reasonable space velocities. Benzene, toluene, or xylene are not produced from, say, *o*-cresol, which disproportionates to phenol and selective xylenol isomers. In the CFRI development the concept of trans-alkylation has been adopted, where from a high boiling phenol and a low boiling one (phenol itself, for instance), an intermediate phenol is produced. Thus, starting with xylenols and phenols, as much as 70 mole per cent yield of cresols (based on xylenol), is obtained.

On the basis of these developments, a conceptual scheme for the phenolic section of such coal-to-oil plants has been put

*Based on a paper by T. J. Bhaduri *et al.* (under publication).

forward. After selective solvent extraction with aqueous ammonia the raffinate, after separating the neutral and basic components, shall be charged to the transalkylator along with phenol from the fractionation unit (only make up volumes of which will be needed after steady state conditions have been reached). The products from the transalkylator shall be recycled to the ammonia extractor. Phenols can be separated from the extract phase by standard solvents used for dephenolizing ammoniacal liquors, like butyl acetate or di-isopropyl ether. This extract can then be fractionated to get back the dephenolizing solvent and receive product streams of phenols, cresols and xylenols, of which the phenol will be fed to the transalkylator. It has been shown that cresols production can be easily more than doubled using this scheme even at the present stage of development.

Further work for studying the feasibility of the proposed scheme and for modifying and improving it is under progress.

Hard Coke Requirements—A Survey — *contd from p.* 111

For meeting short-term requirements, it may be worth while setting up beehive ovens which involve lower capital investment and short time for construction with no foreign exchange commitment and can be built for small capacities at pitheads. Provided good quality coals are fed and care in operation is taken, beehives can produce good quality coke for foundries.

With provision of price incentive for superior grade foundry coke, the beehive ovens can produce quality coke for the Indian market. During last two years, the CFRI has done a considerable consultancy work in setting up of or in improvement of existing beehive ovens in the Bihar-Bengal coalfields. With expansion of demand to an optimum level of both coke and byproducts, the beehive ovens can give place to byproduct ovens of economic size in due course.

Notes & News

Dr C. V. Raman

Born at Trichinopoly in November 1888, Chandrasekhara Venkata Raman obtained his M.A. degree in Physics with high honours from Madras University at the early age of 18. While still a student at Presidency College, Madras, he began original research work on acoustics and optics.

In 1915, Sir Asutosh offered him the Sri Tarak Nath Palit Chair of Physics at the University College of Science which he accepted after resigning his government job. In 1924, barely six years after he became a Professor of Physics, he was elected a Fellow of the Royal Society.

Since 1925, Porf. Raman was engaged in working out a theory of the well-known Compton Effect on the basis of the classical ideas. Experimental tests carried out by him with the aid of a mercury arc and a pocket spectroscope established the fact that the scattering of light with a change of frequency is exhibited by materials of the most diverse chemical nature in many cases manifesting itself as sharply defined spectral lines in displaced positions. This work on the molecular scattering of light culminated in the discovery of a new phenomenon which came to be known as 'Raman Effect'—a fundamental aspect of optics. According to this discovery, light scattered by any medium contains frequencies differing from that of the incident light by amounts which are characteristics of the scattering medium. These characteristics of Raman frequencies are equal to the infrared frequencies of the substance and are caused by energy interchanges between the incident light and the scattering substance. However, some frequencies appear in the Raman spectrum which are 'forbidden' in the infrared and vice versa so that studies of infrared and Raman spectra complement as well as confirm one another. In 1930, he was honoured with the award of the Nobel Prize in Physics for his discovery of Raman Effect.

Prof. Raman later turned to crystallography and his interest in this branch of science continued for years and in 1948 he attended the first International Congress of Crystallographers at Harvard.

In 1933, he went to Bangalore as Director, Indian Institute of Science. Four years later he relinquished his Directorship but was the Head of the Physics Department till 1948 when he founded the Raman Research Institute at Bangalore. He also started the Indian Academy of Sciences, of which he was the President till his death.

In 1962, Prof. Raman discovered new clues to crystal structure and behaviour. His research on fluorspar had revealed new facts concerning the effect it displayed and these pointed to an explanation of a phenomenon altogether different from what had gained credence. In 1968, he discovered a very wide range of floral colours arising from the presence of a set of discrete and well-defined bands in the absorption spectra of the flower.

Prof. Raman's important publications included diffraction of X-rays, theory of musical instruments and numerous papers on diverse topics in physical sciences.

The honours received by Dr Raman were innumerable. The British Government conferred knighthood on Prof. Raman. In1921, he represented Calcutta University at the Empire Universities Congress in Britain. In 1924, he was invited to the U.K. to join the British Association for the Advancement of Science in a tour across Canada. At the Toronto meeting of the British Association and of the International Congress of Mathematicians, he opened a discussion on the scattering of light. Subsequently, he visited the USA to represent India at the centenary of the Franklin Institute at Philadelphia. While in the States, Prof. Raman accepted the invitation of Prof. R. A. Millikan and spent four months at Pasadena as a visiting Professor to the California Institute of Technology. He returned to India early in 1925 but again the same year visited Europe as a guest of the Russian Academy of Sciences at its bicentenary celebrations in Leningrad and Moscow.

In 1929, he was invited by the Faraday Society to open a discussion on molecular spectra. Amongst the many scientific honours may be mentioned the award of the Matteucci Medal in 1928 and of the Hughes Medal of the Royal Society of London in 1930. He received the Ph.D. degree of the University of Freiburg and the LL.D. of Glasgow University in 1930 and the D.Sc. of the University of Paris in 1932.

Almost all the Universities of India conferred Honorary Doctorates on him. He was an honorary member of the Deutsche Akademi of Munich, of the Zurich Physical Society and of the Royal Philosophical Society of Glasgow, of the Royal Irish Academy and of the Hungarian Academy of Sciences. He was an Honorary Member of the Indian Mathematical Society, of the Indian Chemical Society and of the Indian Science Congress Association. He was General President of the Indian Science Congress in 1929. In 1937 as an invitee, Porf. Raman took part in the International Congrees of Physics held in Paris. In 1941, he was awarded the Franklin Medal of the USA. He was also elected an Honorary Fellow of the Optical Society of America and a Foreign Associate of the French Academy. He was also elected Corresponding Member of the Russian Academy of Sciences. In 1948, he attended the International Conference on "Diffusion Moleculalre de la Lumiere et L'Effect Raman" at Bordeaux. He was appointed National Professor of Physics in 1949 and was awarded the 'Bharat Ratna' in 1954, the very first year of the inception of State Awards. In 1961, the Vatican nominated him for election to the Pontifical Academy of Sciences.

■ The XIII seam of Jharia coalfield has been assumed to be parent coking coal and is estimated to contain about 124 m. tonnes of coal up to a depth of about 150 metres in working collieries. The good quality is expected to be maintained throughout the field and the seam is expected to contain about 299·4 million tonnes of coal up to a depth of about 300 metres. The above finding was announced in the recently concluded Advisory Committee Meeting for Coal Survey Laboratory (CFRI), Jharia, held under the Chairmanship of Mr S. K. Nargundkar, Executive Adviser, East India Coal Co. Ltd., Dhanbad.

Physical and chemical survey has further revealed that contrary to the current belief, the coal of VIII seam is found to contain parent coking coal, particularly in the eastern zone. The VIIIA seam in the western region of the Jharia coalfield is indicated to possess medium coking coal suitable for use in coking blends only with matching coals. The reserve is estimated at about 12 m. tonnes up to a depth of about 150 metres in working collieries.

Through exploration survey in the Bhojudih area, GSI has found the occurrence of two unidentified seams underlying XVII seam. Analyses of the coal cores at the Jharia Survey Laboratory proved that the unidentified seams contain high volatile, strongly caking coals (C.I. 18-23) with the bottommost seam (5·33 m. thick) having no dirt bands. As a result, the ash percentage of the coal of this seam has come down to about 14.

Analyses of the coal cores from Jarma Block, sent by NCDC, has indicated that XV seam is quite thick in the area and holds strongly caking (C.I. 19-24) coals with 16-17 per cent ash. The seams on either side of it have been affected by igneous intrusion. The coal from the seams of an adjoining area has been found to be high in ash but strongly caking.

Coal cores from Raniganj Measure Basin were also analysed and found to be of high ash (25-32 per cent), but strongly caking in nature. Another characteristic feature for these coal is the high volatile matter content (35-38 per cent).

Investigations for judging the suitability of lower seam (I-VIIIA) coals in the outcrop regions for domestic use have revealed that only the fines (below 20 mm.) are suitable for the purpose after briquetting.

■ The feasibility report on the integrated utilization of Kutkona coals for making formed coke for use as domestic, ferro alloy and metallurgical cokes prepared by CFRI in collaboration with the Coal Survey Laboratory, Vilaspur, for the MP Audyogik Bikash Nigam, was the major topic of discussion in the Nineteenth Advisory Committee Meeting for the Laboratory held under the Chairmanship of Mr C. Balaram, Director (Tech.), NCDC, Ranchi.

Based on the analyses and tests carried out at the Coal Survey Laboratory (CFRI), Bilaspur, the Churcha coals were found suitable for blending (now being used as a blend component for Bhilai Steel Plant) as well as for domestic/metallurgical formed coke production. The various aspects of the utilization of these coals were also discussed in the meeting.

The project envisaged is an integrated scheme for utilization of the entire run-of-mine production (1500 t/d) of coals from the Kutkona Block of NCDC, the lump coals being carbonized in Vertical Retorts and small coals used for formed coke making. The combined tar will be treated for recovery of phenols, flotation and creosote oils and binders. Production of electrode binders may also be possible. With doubled production in the second phase, extraction of iron with formed coke can also be undertaken in blast furnaces. The retort gases can then be used for synthesis of chemicals or fertilizers.

Studies on Bisrampur, Kurasia and Jhingurdah coals indicated that the coals are suitable for steam raising, combustion, power generation and other industrial uses.

Analyses of bore hole cores from Gorbi Block, Singrauli coalfield, indicated that the coals would be suitable for the proposed Bhatinda Power Station in Punjab and Bhandarpur Power Station near Delhi.

At the instance of M/s Renusagar Power Company Ltd., the laboratory carried out beneficiation studies on Jhingurdah coals and suggested three schemes, any one of which guaranteed improved and reasonably consistent supplies of coal to the Renusagar Power Station.

In absence of any outlet and continued accumulation at the colliery site, dust coal from Bisrampur colliery was subjected to beneficiation studies. Laboratory and pilot plant trials showed that it would be necessary to wet screen the coal at 3 or 1·2 mm. on special type of screen followed by hydrocyclone washing of the minus 3 or 1·2 mm. slurry. By this simple process of upgrading, about 85-90 per cent of the dust coal can be recovered with an ash content of nearly 17 per cent from a level of about 22 per cent in the raw small coal (below 6 mm.). A report has been prepared incorporating the results and submitted to the NCDC.

The laboratory also carried out tests on the suitability of different coals for formed coke production in collaboration with M/s Chemical & Metallurgical Design Co. Ltd., the Technical Consultant of NCDC, for a Formed Coke Project. Talcher and Churcha coals were selected for the purpose. The results have been incorporated in the feasibility report submitted by the consultants to the NCDC. The production possibilities of domestic and industrial coke with Churcha coals appear to be bright.

■ The Advisory Committee of the Coal Survey Laboratory (CFRI), Nagpur, meeting on 31 August 1970 with Shri K. I. Vidyasagar, Managing Director, the Singareni Collieries Co. Ltd., Hyderabad (A.P.), in the Chair, was apprised of the studies of the Laboratory on the coals from inclines 6 and 7 of Godavari Valley coalfield. It was found that these coals could be used for combustion, steam-raising, power generation and other industrial purposes.

Preliminary investigations, undertaken at the instance of the Directorate of Geology & Mining, Government of Maharashtra, to judge the suitability of Wardah Valley coals for formed coke production was not encouraging. However, further studies are on hand.

Quality assessment of borehole cores, a continuing work of the Laboratory, had earlier helped NCDC to open up a colliery in Silewara area of Kamptee coalfield to meet the demands of coal for the Khaperkheda Thermal Power Station. The same help was rendered last year also in connection with the opening up of another new mine in the area which would supply the coal requirements of proposed 1080 MW Super Power Plant at Koradi

Coal cores from Pathakhera coalfield were also tested for proving further reserves of coal for the Satpura Thermal Power

Station. Low and medium temperature carbonization yielding domestic coke and other valuable byproducts was considered to be another mode of utilization of these coals.

Like earlier samples, the coal cores from Damua and Gargunda areas, Pench-Kanhan and Tawa Valley coalfield analysed during the year under review, indicated their suitability as a blendable coal. Further investigations are considered necessary for confirmation.

Coals from bore hole cores from Mohpani coalfield were analysed and found to be of a maturer variety (carbon per cent, 87·9 and hydrogen per cent, 4·9). Contrary to other coals of same maturity from other coalfields, these coals were completely non-caking. The coals might be suitable for power generation and for combustion.

Another important project recently undertaken by CFRI at the instance of Gujarat Government was the feasibility study on the utilization of Kutch lignite. The Coal Survey Laboratory would analyse and supply data for the project.

Technology in the Seventies: A CSIR Science Reporters' Symposium

The CSIR Science Reporter organized a two-day symposium on 'Technology in the seventies' in New Delhi on 9 and 10 July 1970. Besides a session on 'Technological policy in the seventies', there were three sessions at which problems, policies and trends of development in three specified areas, viz. (1) Electronics and Communication, (2) Chemicals and Petrochemicals, and (3) Metallurgy and Heavy Engineering, were discussed. Eminent men from government departments, research institutions, industry and the press were invited to initiate discussion. In all, thirteen papers were presented. A large number of delegates from various organizations participated in the deliberations of the symposium. Shri S. Ranga Raja Rao represented CFRI.

Urging for the formulation of a technological policy resolution, Dr Atma Ram, Director-General, Scientific & Industrial Research, said that the Science Policy Resolution, which was accepted by Government some years ago, was not enough in view of the fact that translation of science into practice requires a sound technological policy. The technological policy, Dr Atma Ram suggested, should determine priorities in research, allocation of funds according to the priorities, and development of technologically competent manpower. The resolution must spell out in clear terms the course the country should adopt in the field of technology so that funds allocated for scientific research are utilized for the benefit of the common man.

Discussing the motivations and objectives for the formulation of a technological policy, the following were considered essential: (1) Creation of necessary conditions to ensure highest priority to the utilization of indigenously developed technology; (2) import of technology only when such technology is either not available indigenously or where economic factors do not permit of the time involved in indigenous research being undertaken at that stage; in all such cases the technology imported must be a compatible technology; and (3) the R & D organizations in the country should initiate further research and development starting with this compatible technology.

Discussions at the various sessions devoted to specific areas dealt with the experiences of the past, the prospects for the future and the problems needing solution, and provided broad directions for the planning of R & D effort in these areas.

In the field of metallurgy, the promising lines of development enumerated were: setting up of less number of blast furnaces with higher steel capacities; use of sinter to improve the blast furnace productivity; use of iron ore pellets as blast furnace feed; increased use of large sized LD oxygen converters in place of hearth furnaces; and use of continuous steel-making processes based on counterflow of slag in open hearth plants. Emphasis was laid on the intensification of R & D effort towards development of non-ferrous industry. In the field of chemicals stress was laid on the prime importance of catalysis, the growing field of synthetic fibres, plastics, detergents, carbochemical industry including synthetic oil, coal-based industry.

Referring to under-utilization of capacity in the heavy engineering industry, it was felt that the idle engineering capacity could be fully utilized if there was a changeover from product classification to process classification of industrial capacity.

Shri K. C. Pant, Minister for Scientific & Industrial Research and Electronics, and Vice-President, CSIR, in his concluding address, pointed out that it was essential to know the course of technology in certain sectors of industry, such as metallurgy, heavy engineering, electronics, petro-chemicals and synthetic fibres. Technological forecasting should also include attempts to determine priorities in research and allocation of resources in order to achieve a given set of goals. The Minister emphasized the point that technological forecasting should become a part and parcel of our general planning processes.

National Fuel Policy Committee

The Government of India have been considering for some time past the question of formulating a long-term Fuel Policy. The Energy Survey Committee, in their 1965 Report, found that our energy resources were adequate, but not abundant. They recommended that it was desirable to keep under review the trends in energy consumption as circumstances change. The energy consumption pattern indicates a growing dependence on liquid fuels although indigenous coal resources are available in abundance. It is considered necessary to evaluate all the available fuel resources in the country with a view to optimizing utilization of the same. With this objective, the Government has set up a high level Policy Committee with Shri R. Venkataraman, Member (Industry), Planning Commission, as Chairman. Dr A. Lahiri, Director, CFRI, is a member of the Committee.

The terms of reference of the Committee are:

(a) Undertake a survey of fuel resources and the regional pattern of their distribution.
(b) Study the current trends in exploitation and use of Fuels.
(c) Estimate prospective demand by sectors (in particular the transport industry, power generation industry and domestic fuel) and by regions.
(d) Study the efficiency in the use of fuel and recommend: (i) the outline of a national fuel policy for the next fifteen years; (ii) a pattern of consumption and measures, fiscal and otherwise, which would help the best use of available resources;

and (iii) the measures and agencies, to promote the optimum efficient use of fuel.

Western Region Mineral Convention

A Mineral Convention of the Western Region comprising Madhya Pradesh, Maharashtra, Rajasthan, Gujarat States and the Union Territories of Goa, Daman and Diu was held at Ahmedabad on 17 and 18 October 1970. About four-hundred delegates, representing various organizations from the States as well as various Central Government organizations like GSI, ONGC, NML, CFRI, CSMCRI, MMTC, Gujarat Oil Refineries, etc., participated in the Convention.

Altogether 39 papers were presented and discussed. CFRI contributed two papers, one entitled "Development of lignite resource of Kutch", by A. Lahiri and the other entitled "Siderite deposit in the eocene formation, Kutch, Gujarat", by B. Banerjee and A. K. Moitra.

Dr Lahiri suggested that for power hungry Gujarat, especially the western part, power generation may be the main avenue of utilization of lignite, of which the available reserves are estimated at 40·9 million tonnes. This method of use will also lead to the recovery of the sulphur which is present to the extent of 2-3 per cent in the lignite. The sulphur recovered from the flue gases can be used for sulphuric acid manufacture. The fly ash, mixed with lime, can be processed into building bricks by a technique recently developed by CFRI. Alternatively, the lignite can be utilized by carbonizing to yield char, tar and gas. Char and gas can be utilized for calcining of minerals and the locally available bauxite and iron ore based industries can be developed. Integrated with power, the calcined ore may also be smelted with electricity. The tar fraction may be used for recovery of phenols and cresols, very much needed by the chemical industry and pitch is useable as binder for electrodes. The high boiling phenols can be used for the production of chlorinated products for agricultural use or for the preparation of a resin suitable for the production of masonite type of hard boards and particle boards from industrial wastes like bagasse, coir fibre, rice husks and a host of such materials. The carbonization process can again be an integral part for the production of domestic/industrial briquettes. CFRI has demonstrated that the char can be bound by a processed tar-binder, briquetted and oxy-hardened to yield suitable domestic/industrial briquettes. Dr Lahiri emphasized that the economics of all these avenues of use will ultimately be determined by the cost of production of lignite.

Sarvasree Banerjee and Moitra reported on behalf of the CFRI that the siderite deposits of Panandhro, Kutch (Gujarat), could be a regular source for the bulk production of hydrogen by the steam iron process. The location of this source is reported for the first time. In view of the increasing demand of hydrogen for various industrial uses (vanaspati manufacture in particular) and the present import of 'spathic iron ore' from Spain, the findings assume considerable significanc e for India.

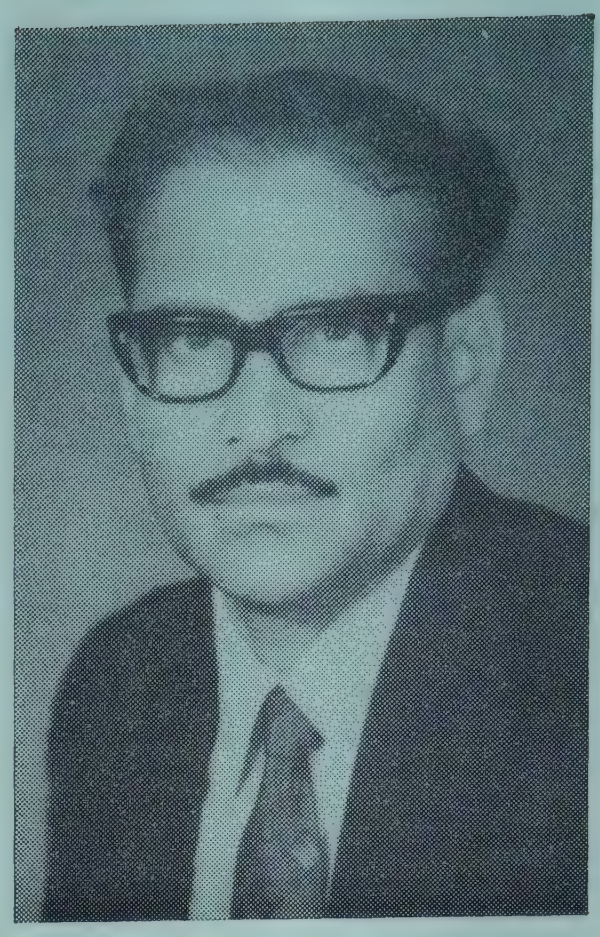
The Convention took a decision to arrange for such meetings of the western region every year. Bombay will be the venue for the 1971 convention.

C. S. B. Nair Awarded Ph.D.

Researches undertaken at CFRI by Shri C. S. B. Nair, Scientist, under the guidance of Dr A. Lahiri, Director, to develop processes for the manufacture of chemicals from coal tar fraction resulted in the Award of Ph.D. Degree (Science) to Shri Nair by the University of Kerala.

The studies covered the oxidation of polynuclear hydrocarbons such as naphthalene, methyl naphthalenes, anthracene and coal tar fractions rich in these compounds to phthalic anhydride and anthraquinone over fluidized beds of catalyst.

The oxidation of coal tar fractions containing predominantly methyl and dimethyl naphthalenes showed that such fractions could yield substantial quantities of phthalic anhydride. It was also shown that tar oils could be used without separating the naphthalene obtained in them whereby yields of phthalic anhydride, far in excess of what was obtainable from the actual naphthalene content, could be realized. Oxidation of tar fractions, however, resulted in the production of considerably more heat than in the case of naphthalene.



Dr C. S. B. Nair

The oxidation of anthracene and anthracene-rich fractions of coal tar was studied in great detail for the production of anthraquinone. A catalyst composition was developed which gave consistently high conversions at high selectivities to anthraquinone. The weight yields of anthraquinone under the optimum condition were 91-96 per cent on the anthracene feed at space, time yields 80, catalyst temperature 370-450 degree C, contact time 2.0 sec. and air/hydrocarbon ratio as low as 11·5.

The oxidation of anthracene was found to be of first order with respect to initial anthracene concentration and 0·9 order with respect to initial oxygen concentration. The production of anthraquinone, phthalic anhydride and carbon dioxide were also found to have a first order dependence on the initial anthracene concentration.

The reactions involved in the oxidation of anthracene were studied following a parallel as well as a consecutive sequence of reactions. It was shown that a scheme of parallel and consecutive reactions could best explain the observed facts. The energies of activation for the individual reactions have been calculated. Under the experimental conditions, the reaction leading to anthraquinone was the fastest. The production of carbon dioxide and phthalic anhydride were respectively 4-5 and 29-33 times slower than the production of anthraquinone

depending on the temperature of oxidation.

G. S. Dwivedi Awarded Ph.D.

Shri Dwivedi, Scientist of CFRI, was awarded a Ph.D. (science) degree by the Indian Institute of Science, Bangalore, for his thesis entitled "Polarographic and potentiometric behaviour of amino acid complexes of uranyl and ferric ions".

Although amino acid anionic complexes of metal ions have been extensively studied, information about the amino acid zwitterion complexes of metal ions are very scanty. Recently some studies on Raman spectra of Zn-glycine systems and polarographic behaviour of uranyl ion in amino acid solutions have indicated that the zwitterions are also capable of forming complexes with metal ions. Based on the above observation, Shri G. S. Dwivedi, while working in Indian Institute of Science, Bangalore, determined the stability constants of U(VI) (UO_2^{++} ion) complexes by potentiometry applying a method used by Bjerrums for the metal-ethylene diamine system.

The studies by Shri Dwivedi show that the complex forming ability of amino acid zwitterions is comparatively much weaker than of amino acid anions. It is considered that further studies on the stability constants of various metal ion complexes of amino acid zwitterions may throw light on the type of linkage which is present between metal ions and proteins.

VISITORS

Union Minister of State for Mines & Metals Visits CFRI

Shri Choudhury Nitiraj Singh, Union Minister of State for Mines & Metals, accompanied by his Chief Technical Adviser, Shri K.S.R. Chari and Senior Officials of the Ministry, and Mr Ranchor Prasad, Managing Director and Chairman of the National Coal Development Corporation, visited the pilot plants of the Central Fuel Research Institute on 21-7-1970. Dr A. Lahiri, Director, CFRI, explained to the visitors the various items of pilot plant work of Institute and gave a detailed picture about the work relating to the use of Madhya Pradesh coals from the NCDC mines such a Kutkona and Churcha, for making domestic, industrial and metallurgical fuel by the CFRI formed coke process. A project report submitted by a leading Chemical Engineering Consulting Firm for the establishment of a 15 tonnes per/hr plant in Madhya Pradesh based on the CFRI process is under the consideration of the NCDC.

The visitors also inspected in detail the CFRI pilot plant and large scale testing facilities for coal gasification. The direct gasification process is to be employed in the three recently approved coal-based fertilizer plants being erected in the public sector. They also saw the work on synthetic oil from coal and coal chemicals division of the Institute.

STAFF MATTER

Promotions

We congratulate the following on their promotion:

(i) *K. Y. Shrikhande* — Dr K. Y. Shrikhande, Officer-in-Charge, Coal Survey Laboratory, CFRI (CSIR), Nagpur, was promoted to Scientist 'E' (1-5-1969) on the recommendation of the Assessment Committee. He took M.Sc.(Tech.) degree in Industrial Chemistry from Banaras Hindu University (BHU) in the year 1948 and Ph.D. degree in Fuel Technology from the same University in 1960.

Dr Shrikhande worked as Research Assistant for about a year at College of Technology, BHU, on a CSIR scheme prior to joining

Dr K. Y. Shrikhande

Shri Choudhury Nitiraj Singh, Union Minister of State for Mines & Metals, accompanied by Dr A. Lahiri, Director, CFRI, during his visit to the Institute

CFRI in 1949, as a Junior Scientific Assistant. At the CFRI, he was promoted to Senior Scientific Assistant (1952), Junior Scientific Officer (1955), Senior Scientific Officer, Gr. II (1958) and Senior Scientific Officer, Gr. I (1961).

During his service at CFRI, Dr Shrikhande worked on diverse problems connected with fluidization, gasification, carbonization (low and high temperature) and briquetting of coal and coke. During 1963-68, besides his laboratory work, he was the Officer-in-Charge, Information & Publication Division, and Chief Editor of the *FRI News*. Since January 1969 he has been acting as the Officer-in-Charge, Nagpur Coal Survey Laboratory (CFRI).

Dr Shrikhande visited USA in 1952 on selection as a member of the Foreign Students Summer Project, M.I.T., where he studied 'fluidization techniques'. In 1957, he was deputed under Colombo Plan to Fuel Research Station,

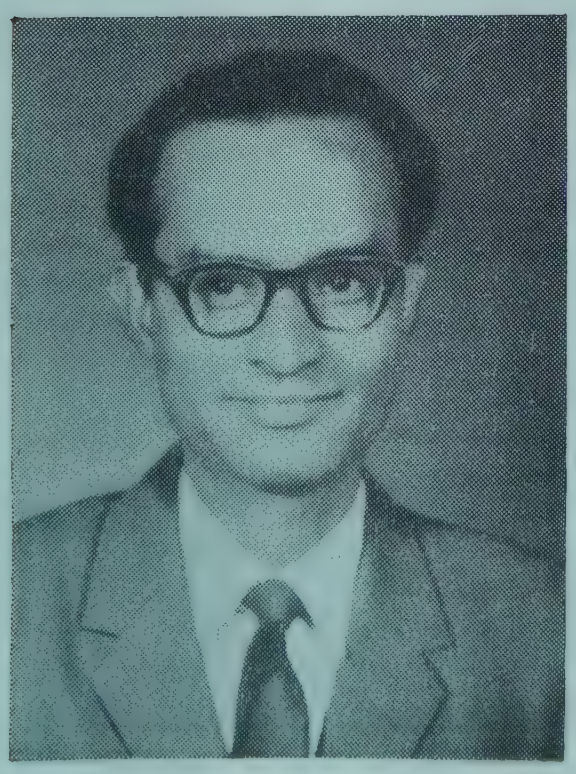
U.K., where he received training on low/medium temperature carbonization of coals in narrow continuous vertical retorts.

Dr Shrikhande is a Fellow of the Institute of Chemists (India), a Member of the Coke Oven Managers' Association (COMA), U.K., and Member of the Executive Committee of its Indian branch and an Associate Member of the Institute of Fuel, U.K., formerly Joint Secretary, now a Committee Member of its Indian branch. From 1954 to 1967, he was a Senior Member of American Chemical Society. Dr Shrikhande served the ISI Domestic Coke Committee (Soft Coke Sub-Committee) from 1962 to 1968 as CFRI representative.

Dr Shrikhande has published 46 research/review papers jointly or as single author. He has taken two patents and has contributed to the preparation of a large number of technical reports.

(ii) *Shri N. C. Sinha* — Shri N. C. Sinha, promoted to Scientist 'C' on the recommendation of the Assessment Committee, took his B.Sc.(Hons.) degree in Chemistry from the Dacca University in 1943.

Joining CFRI in May 1950, Mr Sinha had intensive training in coal survey techniques and problems of efficient utilization of Indian coals. He underwent post-graduate training in statistical methods at the Indian Statistical Institute and at the International Statistical Education Centre, Calcutta (under the aegis of UNESCO). He was associated with the statistical cell of CFRI since its inception where he and his colleagues are working on: (i) formulation/



Shri N. C. Sinha

Shri T. J. Bhaduri

revision of Indian Standards Specification on sampling of coal and coke and on the determination of their pulverizing properties; (ii) correlation and regression analysis and other statistical methods as applied to fuel research problems; and (iii) energy survey, planning and forecasting.

From CFRI, Shri Sinha was deputed for training in OR methods, modern methods of data processing, FORTRAN programming using IBM 1920 and IBM 7044 computers.

Shri Sinha has to his credit 22 research papers and 10 review articles. Shri Sinha was elected a Fellow of the Royal Statistical Society (UK) in 1966.

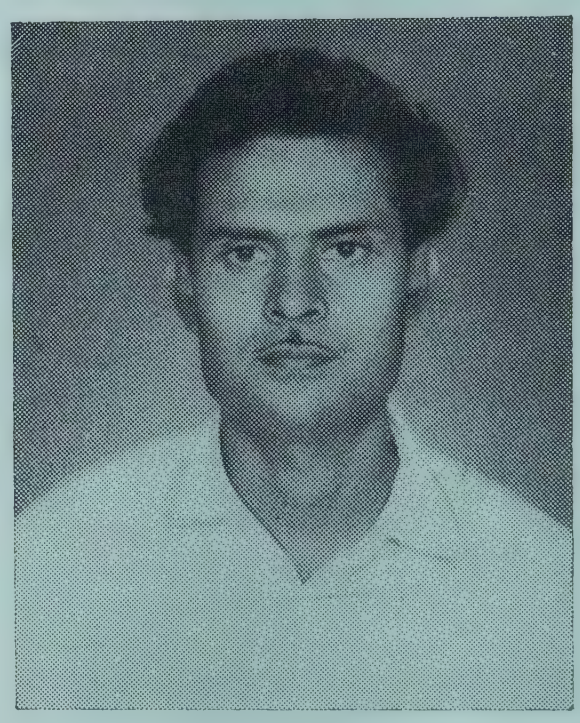
(iii) *Shri T. J. Bhaduri* — Shri T. J. Bhaduri promoted (6-8-1969) to Scientist 'C' by the Assessment Committee, took his M.Sc.(Tech.) degree from Calcutta University in 1961 with specialization in Chemical Engineering, and joined CFRI as a Senior Stipendiary in the same year. He was absorbed in the regular services of CFRI as SSA in 1962 and promoted to Scientist 'B' in 1964.

Specializing in the chemistry of phenols, Shri Bhaduri first took up the problem of their extraction from coal tar and coal hydrogenation oil sources and developed a cheap indigenous solvent for the preferential extraction of the commercially useful lower phenols. He followed this with study of the problem of conversion of high boiling phenols to their more useful lower members and succeeded in developing a catalyst which obviated the neutral formation, the major lacuna in the conversion. Simultaneously, he had also been associated with the projects group for making feasibility studies of coal-based industrial complexes and with Dr E. E. Donath, the US expert on coal hydrogenation, to formulate the recommendations for hydrogenation of Assam coals.

In 1966 Shri Bhaduri was deputed to West Germany to participate in the 2nd International Seminar on Physical Chemistry, Chemical Technology and Chemical Engineering, where he learnt German language, took courses in Radiochemistry, Unit Operations and Corrosion Technology and worked with Prof. Helmut Pichler on the hydrocracking of model hydrocarbon compounds.

Literature, music and bridge are his hobbies.

(iv) *Shri A. Majumdar* — Promoted to Scientist 'C' (w.e.f. August 1969), Shri Majumdar graduated in Science with Honours in Chemistry from the Calcutta University in 1952 and took his Bachelor degree in Chemical Engineering from the Jadavpur University in 1956.



Shri Animesh Majumdar

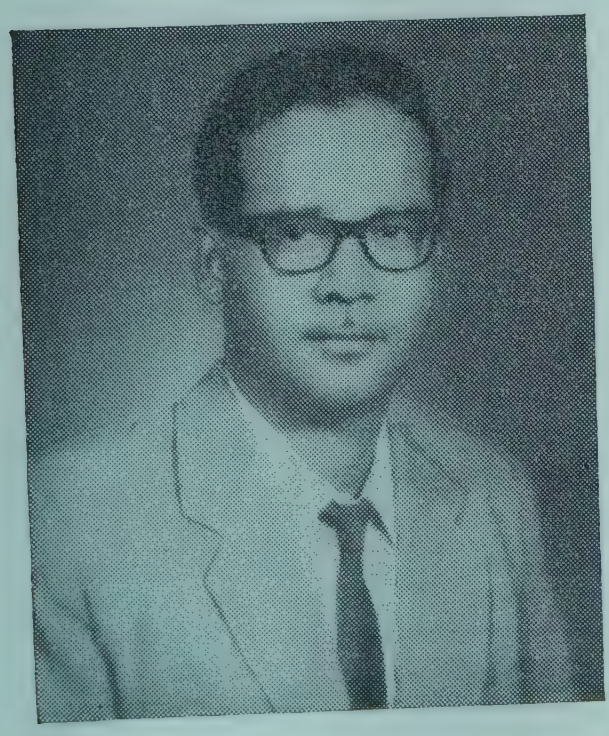
Before joining CFRI in December 1958 as STA, Shri Majumdar underwent practical training for one year as apprentice Chemical Engineer with M/s Bengal Immunity Co. Ltd. and gained first-hand experience in design of chemical equipment and processes. Subsequently he was appointed as Chemical Engineer in the Design and Development Section of the DCM Chemical Works, Delhi, and later as Chemical Engineer-cum-Research Chemist in the Industrial Research Laboratory under the Director of Industries, Government of W. Bengal. He also worked as a Lecturer in Chemical

Engineering for the Paint Technology Course conducted by the Director of Industries, Government of W. Bengal.

At CFRI, he was promoted successively to Junior Scientific Officer and then to Scientist 'B' and now he is Scientist 'C'. During this period he was associated with pilot plant projects dealing with steam-oxygen gasification of coal, both at atmospheric and elevated pressures. He worked with the German operating engineers of Lurgi Gesellschaft Fur Warmetechnik G.m.b.H. during the commissioning of the CFRI High Pressure Gasification pilot plant. He has also gained experience in operation and maintenance of high pressure plants and equipment. He was associated with design work of pilot plants for the manufacture of hydrogen gas from synthesis gas, water gas from coke, etc.

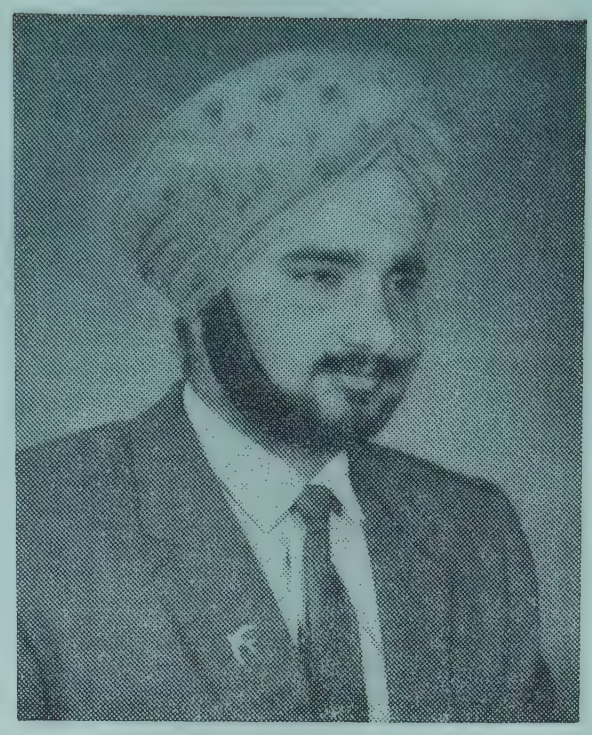
Based on his work as a member of the team working on coal gasification, he has published as co-author many papers and reports.

(v) *Shri R. N. Bose* — Shri R. N. Bose has been promoted to the post of Scientist 'C' at CFRI with effect from 6-8-1969. He obtained his B.Sc. from the Patna University in 1946 and served the TISCO collieries as a Research Assistant for about 2 years before joining CFRI in 1949.



Shri R. N. Bose

During his service at CFRI for over two decades, Mr Bose has been working on various research problems, particularly in the field of sampling, grindability and beneficiation of coal. He is currently engaged in operational research and quality control problems of coal washeries in India.



Shri Kunda Singh

He has to his credit 28 research and review papers published in both Indian and foreign journals.

Shri Bose is a member of the Indian Institute of Mineral Engineers and the Indian Society for Quality Control. He is also serving as a member of the Coal Washeries Panel set up by the Indian Standards Institution.

Shri Bose was deputed for advanced training in statistics at the Indian Statistical Institute, Calcutta, sponsored by UNESCO during 1954-55 and attended a short term course in 1969 on Modern Developments in Mineral Engineering Practice at IIT, Kanpur.

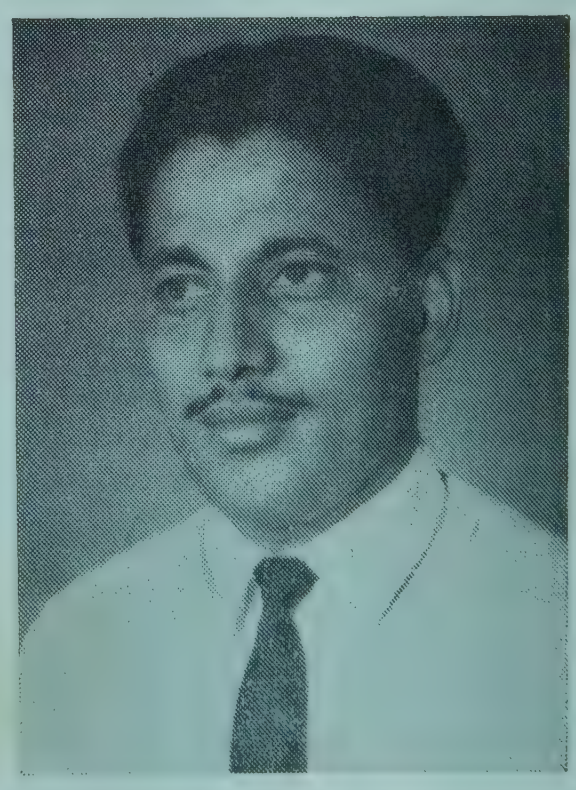
(vi) *Shri Kunda Singh*—Shri Kunda Singh promoted to Scientist 'C' (w.e.f. 25-11-1969) on Assessment, joined the Central Fuel Research Institute in February 1956, after his graduation from Delhi University. After working for about a year on the testing of coal, coke, tar, liquor and gas, Shri Singh was transferred to the Carbonization Division where he was a member of the team dealing with various coke oven plant problems. He also collaborated in the research work for the selection of coking blends for different steel plants and other commercial coke ovens, and was associated with the coking tests in commercial coke ovens at TISCO in collaboration with CBCR, Jamshedpur. Degradation in size and improvement in physical strength of the coke during its transit from wharf to skip in steel plants was another project with which he was actively connected.

He has been associated with CFRI teams which studied: (a) 'roof carbon' trouble in the coke ovens of Durgapur Project (1966); (b) lower production of ammonium sulphate from the coke ovens and byproduct plant of the Durgapur Steel Plant (1968); (c) lower yield of byproducts from the Bararee coke ovens and byproduct plant at Kuskunda; and (d) lower yield and poor quality of coke from the beehive ovens at (i) Bhulan Bararee (Jharia field), (ii) Namdung (Assam), and (iii) Kharkharee (Jharia field).

Shri Singh is a co-author of 17 papers published in Indian and foreign journals (one paper was awarded silver medal by COMA (UK) in 1964 and has been associated with the preparation of a large number of technical reports.

In June 1970, Shri Singh was deputed to Poland for 6 weeks under the exchange of scientists programme for studying the research work being conducted there in the field of coal carbonization and production of formed coke.

(vii) *Shri M. V. P. Menon* —Shri M. V. P. Menon, who was promoted to Scientist 'C' recently on Assessment, joined CFRI's Raniganj Coal Survey Laboratory in 1954 after graduation from Madras University. He was transferred to Carbonization Division in the same year. He has gained considerable experience in analysis and testing of coal, coke and byproducts from carbonization of coal and has extensively handled problems on sampling of coal and coke, selective coal preparation, blending, stamping, development of methods for testing coal and coke and low and high temperature carbonization of Indian coals. He is also a member of the teams undertaking investigational work into operational



Shri M. V. P. Menon

troubles in industrial coke plants and beehive ovens in India. He has also taken part in guarantee tests at coke ovens, of FCI, Sindri and Durgapur Coke Ovens Project. He is a joint author of over twenty papers published in foreign and Indian scientific journals and has been associated with preparation of a large number of technical reports. One of his papers entitled "A study of the vertical shrinkage of coal on carbonization" in joint authorship has been awarded a silver medal in 1964 by COMA, UK.

■ Sarvasree A. Bhattacharya, O. K. Guha, S. Roy, P. Bhattacharya, S. K. Mukherjee, D. K. Bandyopadhya, S. Gupta, P. K. Mitra, R. K. Bhattacharya, P. B. Sarkar, D. R. Chatterjee, D. D. Banerjee, R. N. Basak, Sudhir K. Mukherjee, Subir K. Mukherjee, A. K. Gupta, M. N. Juneja, S. Biswas and V. S. Saxena as Scientist 'A'/Scientist 'A_1'.

■ Sarvasree K. C. Nath, D. P. Nag, M. Prasad, A. K. Chatterjee, M. P. Sharma, D. N. Singh, D. S. Chatterjee, S. R. Dwivedi, K. Alam Khan, K. K. Tewari, B. C. Gogai, A. B. Chakraborty, and A. K. Nandi as Senior Scientific Assistants.

■ Sarvasree T. K. Goswami, A. Das, S. Basu, D. K. As, D. Biswas, R. Jha, B. Sinha, R. K. Ghosh and P. N. Singh as Junior Scientific Assistants.

Appointments

We welcome the following as members of staff of the Institute: (1) Drs G. Singh, A. K. Choudhuri, C.K. Das and Sarvasree A. K. Samanta and B. Prasad as Scientist 'B'; (2) Dr S. C. Chakravorty as Pool Officer; (3) Dr K. P. Gupta and Sarvasree A. Bhattacharjee and S. Sarkar as JSA; (4) Shri K. P. Raja Ram as Assistant; and (5) Shri V. D. Singh as SSA.

Deputation

Shri N. C. Sinha, Scientist, proceeded to U.K. on deputation under Colombo Plan for training in the field of abrasiveness and grindability of coals. The period of his training will be 3-4 months and he will be attached to British Coal Utilization Research Association. Shri Sinha left CFRI on 15-11-1970.

Transfer

We express our good wishes to Shri Kuldip Rai, Section Officer, who has been transferred (7-11-1970) to Central Public Health & Engineering Research Institute, Nagpur, and to Shri K. P. Banerjee, Assistant, on his temporary officiating promotion vice Shri Rai.

Honours, Elections and Awards

We congratulate: (i) Sarvasree A. K. Sengupta, Scientist 'A' and B. B. Brahmachari, STA, who have completed the Examinations for the Associate Membership of the Indian Institute of Chemical Engineers. (ii) Shri R. N. Bhattacharya, STA, who has been elected a member of the Combustion Institute (Indian Section), U.K.

Retirement

We express our best wishes to Shri S. Chatterjee, Assistant Director (Engineering), on his retirement from 16 October 1970 after serving the CFRI for more than two decades and pray for his long and peaceful life after superannuation.

Born on 16 October 1910 in Nadia District (E. Pakistan), Shri Chatterjee had his early education at Berhampur and higher education in B.E. College, Sibpore, wherefrom he had his B.E.(Mech.) degree in 1934. A brilliant student all through, he won Ashutosh Memorial Medal for securing the first place in Mechanical Engineering (Theoretical) as well as a prize for proficiency in Electrical Engineering in his degree examinations.

After fifteen years of association with leading design and engineering firms, Shri Chatterjee joined CFRI in April 1949 as Junior Scientific Officer and was promoted to Senior Scientific Officer in 1951 and Assistant Director in 1957. Throughout his service at CFRI he was in-Charge of the Drawing and Engineering Division of CFRI. In 1959 he was deputed to France under the Indo-French Technical Cooperation Scheme to study the design, construction as well as techniques of fabrication of pilot plants in the field of coal and petroleum technology. He has been an Associate Member of the Institute of Engineers (India) since 1950.

CFRI ABSTRACTS

RECENT DEVELOPMENTS IN COAL PREPARATION PRACTICE: A REVIEW, by B. B. Konar [*J. Min. Met. & F.*, Dec. 1969].

The paper deals with the more recent progress and developments in the field of coal preparation. The subject has been discussed under five main divisions, namely (i) pretreatment of raw coal, (ii) washing, (iii) dewatering, (iv) drying, and (v) plant control. Development of new coal washing equipment, improvement in coal preparation techniques and the increasing use of instrumentation, automation and operation research results in the increased efficiency of washing, better plant performance and the production of quality product at a competitive price have been also discussed.

A CONCEPTUAL STRUCTURE FOR ASSAM COAL*, by N. V. R. Appa Rao, G. S. Murty, H. S. Rao & A. Lahiri.

Infrared spectra of Assam (Baragolai) coal and its gamma-picoline extract were obtained. High resolution proton magnetic resonance spectra of gamma-picoline extract of Assam coal was studied. Based on the spectroscopic evidence and other chemical data, a conceptual structure of 'Stringed rafts in an eddy' is suggested for the coal.

SOME FEATURES OF JARANGDIH BLOCK IN EAST BOKARO COALFIELD, by S. K. Mookherjea & S. Bagchi [*J. Min. Met. & F.*, May 1970].

Deep drilling in Jarangdih block which is flanked on either side by Gobindpur-Pichri and Borea faults reveals some interesting phenomena. Coal seams touched within the trough are found to have attained greater maturity than the same seams encountered outside the trough. Greater stress and strain due to heavy faulting and possibly greater depth of burial are likely to be the cause of greater maturity of coals within the trough. Possibly dynamic shearing strain due to heavy and extensive faulting on either side of the trough had led to rise in temperature and, if so, this has been possibly the main cause of increased maturity in coals of the region. These coals, which appear to have all the requisite properties of prime coking coals, would go a long way in supplementing and conserving the fast depleting resources of coking coals.

SOLVENT EXTRACTION OF COALS*, by Jyotibhusan Roy & A. Lahiri.

A review of the present status of different mechanisms of solvent extraction of coal and its structural implication is presented. The physico-chemical aspect of different solvents and catalysts has been elucidated. The micellar colloidal structure and mixed isogel concept can adequately describe the solvent action on coal, particularly when considerable amount of energy (in the form of heat, for example) is necessary to disperse the complex coal matrix. The role of surface active agents in increasing the yield of extract can thus be explained.

Van Krevelen's approach to solvent action on coal from the standpoint of thermodynamics by using Flory's theory for solution of polymers has been discussed. The application of this theory is based on the relationship between the change of free energy on one hand and entropy of mixing and an interaction parameter on the other. From a calculation of solubility parameters of coal and solvents, the relationship between solubility and rank of coal has been established in the above treatment. The underlying assumption in the above theory is that the coal-solvent system is akin to rubber-benzene type rather than agar-agar-water type.

Chemical and electrolytic reduction are associated with depolymerization of coal along with consequent increase in solubility. The applicability of current theories of heterolytic and homolytic cleavage of structural link, namely carbon-carbon, carbon-oxygen bonds, accompanied by release of small units, easily disperseable in suitable solvents have been studied. The recent work of almost complete solubility of alkylated coal in benzene has also been reviewed.

AROMATIC POLYCARBOXYLIC ACIDS BY NITRIC ACID OXIDATION OF COAL AND THEIR POTENTIALITIES*, by B. K. Mazumdar, A. Banerjee, J. M. Sanyal, S. Ganguly, A. K. Chatterjee, P. K. Sanyal & A. Lahiri.

Oxidative degradation of coal by nitric acid has been studied and mechanism for the reaction is advanced. The aromatic polycarboxylic acids, prepared by this method, have been found to be mostly nitro-substitute, their yields varying between 40 and 100 per cent, depending on the rank of coal. Higher the rank of coal, higher is the yield of such bodies.

It is noted that successive action of conc. nitric acid can completely oxidize coal to water-soluble products which have been found to be immune to further degradation by concentrated acid or fuming nitric acid. On the basis of preliminary studies on the equivalent weight, molecular weight, elementary composition as well as some characteristic reactions of the products of oxidation, it is suggested that the major component could possibly be nitro-phthalic acid and/or its anhydride, contrary to the findings by others.

Pending complete separation, isolation and identification of the different components in the poly-acids, attempts have been made to prepare phthalein derivatives such as phenol-phthalein, fluorescein and eosin. The yields of such nitro-phthalein derivative have been found to be significantly high varying from about 100 to 250 per cent (of the poly-acids), depending on the type of products derived. The elementary composition and behaviour of such derivatives compare favourably with those of the corresponding standard substances, prepared from standard nitro-phthalic anhydride.

The significance of these tentative findings is discussed in regard to the potentialities of these organic acids as intermediates for production of industrial products and chemicals directly from coal.

**Symposium on Chemicals and Oil from Coal, held at CFRI from 6 to 8 December 1969.*

A Study of the State of Nitrogen in the Nitrogen-enriched Coal (Coal Fertilizer)*, by L. V. Ramachandran, D. S. Chatterjee, P. N. Mukherjee & A. Lahiri.

Alkaline permanganate oxidation of coal fertilizers has been studied from the standpoint of distribution of nitrogen in different forms in the oxidation products. Nitrogen fixation in coal was found to be a function of the rank of coal as well as the time of oxy-ammoniation reaction. The lower the rank of coal and longer the time of reaction, the greater is the nitrogen fixation. With the exception of lignite and coals of higher rank (beyond 86 per cent carbon), the total oxidizable nitrogen decreases with increase in the rank of coal used for the preparation of coal fertilizer. For any particular coal, the percentage of nitrogen oxidized by alkaline permanganate is virtually constant, regardless of the percentage of nitrogen fixation. The distribution of nitrogen in the form of ammonia as well as nitrate ion, on permanganate oxidation, depends, however, on the level of nitrogen fixation. The higher the percentage of nitrogen, the higher is the ammoniacal nitrogen formed on permanganate oxidation and consequently lower the nitrate nitrogen content. The significance of the above findings is discussed in relation to the oxidation behaviour of organic nitrogen compounds.

Catalytic Vapour Phase Oxidation of Anthracene to Anthraquinone*, by C. S. B. Nair & A. K. Ghosh.

Out of a large number of catalysts studied for the vapour phase oxidation of anthracene to anthraquinone, the most promising conversion of 85 per cent was obtained with a CFRI catalyst. The effect of variables, such as temperature of catalyst, space velocity of air, anthracene/air ratio and contact time, has been investigated and the results are presented. Effect of various pretreatments of the catalyst have been determined. X-ray studies revealed the presence of $V_{12}O_{26}$ in the catalyst composition. The oxidation of anthracene has been found to be of the first order with respect to anthracene and of 0·93 order with respect to oxygen concentration. Oxidation of anthracene is considered to proceed in the order: anthracene-anthraquinone-phthalic anhydride-maleic anhydride-carbon dioxide. The oxidation step leading to the production of anthraquinone was found to be the rate-controlling step. The magnitude of the activation energy values obtained points to a surface reaction controlled mechanism.

Rapid GC Analysis of Phenanthrene - Anthracene - Carbazole Mixtures*, by O. K. Guha & A. C. Bhattacharyya.

A rapid isothermal GC analytical method for the analysis of phenanthrene - anthracene - carbazole mixture has been developed with a 2-metre long column packed with 30 per cent cadmium chloride on acid-washed indigenous super insulation brick of −60 +80 mesh. Quantitative analysis was done on the basis of relative detector response (wt basis) taking anthracene as the standard. The method was verified with synthetic mixtures and two purified anthracene samples analysed. Attempts have been made to explain the retention characteristics of the column. The column was found suitable for the rapid analysis of mixtures of condensed aromatics under programmed temperature condition. The column showed stable performance for a long period.

Recovery of Phenols from Coal Tar, by T. J. Bhaduri, D. K. Sen, K. K. Tiwari & C. S. B. Nair.

Investigations undertaken at the CFRI on solvent extraction of phenols from coal tar fractions, using aqueous solutions of acetic acid, acetamide and ammonia have been reviewed. Work done elsewhere on these solvents has been briefly mentioned. The effects of different process variables have been discussed and solvent composition shown to be the most important factor in all cases. Comparative results of multistage extraction methods for improving the purity of the extracted tar acids and their recovery from the extract phase are given.

Anion-exchange Resins from Phenol, Tar Acid Mixtures and the Like*, by P. N. Mukherjee, J. N. Bhowmik, K. N. Rai, I. B. Paul & A. Lahiri.

The properties of an anion-exchange resin developed from phenol, tar acid mixtures, etc., by reaction with formalin and aliphatic amine are discussed. The exchange capacity, regeneration efficiency and swelling characteristics are presented along with the column operation data of the resin. The data on *p*H titration, *p*K values and water sorption are discussed in relation to the structure of the resin. Ammonia was found to be ideal for regeneration of the resin.

Production of Formaldehyde Condensation Products from Tars and Their Utilization in the Manufacture of Hard Boards, Plywood and Moulded Articles, by C. S. B. Nair & D. K. Sen.

Studies have been made on the condensation of crude tar acids obtained from various sources with formaldehyde in the presence of sodium hydroxide. This study covered a wide range of formaldehyde and alkali ratios and resulted in the development of a process for the production of a water-soluble tar acids-formaldehyde condensation product having satisfactory keeping qualities.

This resin could directly be applied on various filling materials, such as sawdust, wood shavings, bagasse, cocoanut pith, jute fibres, asbestos, coir waste, mica dust and the like for the production of good quality boards and moulded articles. The resin could also be used for the bonding of plywood.

The cost estimates for the process indicate good prospects for commercial utilization.

Nitrogenous Bases from Lignite Carbonization Byproducts*, by Subodh K. Ray, G. S. Murty & H. S. Rao.

Nitrogenous heterocycles find extensive applications in the drugs, dyes, pharmaceuticals and fine chemical industries. Although synthetic methods have been recently developed for some of the alkylpyridines, coke oven byproducts still constitute a valuable indigenous source. The composition of the nitrogenous heterocycles in the byproducts of low temperature carbonization of lignite (Neyveli Lignite Project) are presented in this communication. It is observed that low boiling nitrogenous heterocycles (pyridine and picolines) are present in meaningful quantities in Neyveli 'Middle Oil'.

Symposium on Chemicals and Oil from Coal, held at CFRI from 6 to 8 December 1969.

CATALYTIC VAPOUR PHASE AMMOXIDATION OF MONOMETHYL PYRIDINES TO PYRIDINE-NITRILES*, by Sisir K. Ray, P. Bhatta-charya, G. S. Murty & H. S. Rao.

Beta- and gamma-picolines were subjected to catalytic vapour phase ammoxidation over a series of vanadium catalysts in a flow system between 300° and 450°C and at atmospheric pressure. Quantitative data on product composition obtained by the use of absorption spectroscopic procedures variations in product distribution and composition are presented as a function of operating conditions. Beta-picoline on ammoxidation yielded 3-cyanopyridine and a trace of pyridine. Gamma-picoline on ammoxidation yield 4-cyanopyridine, the amide of isonicotinic acid and a trace of pyridine. A mechanism has been suggested fort he ammoxidation of picolines.

SEPARATION AND ESTIMATION OF LOWER BOILING MONOHYDRIC PHENOLS PRESENT IN AMMONIACAL LIQUORS*, by O. K. Guha, A. Bhattacharjee & P. K. Banerjee.

A method for the analysis of phenol, ortho-, meta- and para-cresols present in ammoniacal liquors has been developed by the technique of counter-current distribution.. The method has been verified with synthetic mixture and three ammoniacal liquor samples produced from three different processes have been analysed. Conventional method of determining the partition coefficient from a graph has been substituted by average value. Calculation of the resolution of absorbances of binary mixture has been simplified.

AMMOXIDATION ROUTE TO NITRILES*, by Sisir K. Ray, P. Bhattacharya, H. S. Rao & A. Lahiri.

This paper presents an account of the work carried out at the Central Fuel Research Institute on the production of nitriles from aromatic hydrocarbons and heterocyclics of coal tar origin through ammoxidation, i.e. oxidation with air or molecular oxygen in the presence of ammonia.

Ammoxidation was investigated in a flow system in the range 300-450°C. and at atmospheric pressure on several aromatics and heterocyclics, using spectroscopic techniques for product identification and analysis. With a view to elucidating the mechanism, ammoxidation and ammonolysis of some possible intermediates, especially 4-picoline aldehyde and isonicotinic acid were investigated. The possible role of an acid intermediate in the ammoxidation of aromatics and heterocyclics is discussed.

---

* *Symposium on Chemicals and Oil from Coal, held at CFRI from* 6 *to* 8 *December* 1969.

Chief Editor: S. RANGA RAJA RAO

Editor: SAMIR SEN *Assistant Editor*: R. S. SAHA

Yearly Subscription: Rs. 4 This Copy Re. 1

Available from

CENTRAL FUEL RESEARCH INSTITUTE, P.O. F.R.I., DT. DHANBAD, BIHAR, INDIA

PHONE: JHARIA 6205. GRAMS: RESEARCH, JEALGORA

PRINTED AT THE CATHOLIC PRESS, RANCHI

Registered with the Registrar of Newspapers for India Under No.

R.N. 3872/57

Vol. 21
No. 1 & 2

FRI News

MARCH & JUNE
1971

CFTRI LIBRARY
MYSORE-2A
18 MAY 1972

IN THIS ISSUE

EDITORIAL

(Energy Resources Development in ECAFE Countries) - - 1

FUEL AND ENERGY RESOURCES DEVELOPMENT IN ECAFE COUNTRIES - - 2
A. Lahiri

UTILIZATION OF WEAKLY TO SEMI-CAKING COALS OF MADHYA PRADESH - - 9
B. S. Deshmukh &
A. K. Moitra

NATURAL COKE (JHAMA): ITS PROPERTIES AND POTENTIALITIES - - - - - - 17
S. Gupta

SPOTLIGHT ON SCIENTIFIC ACTIVITIES

SMOKELESS FUEL BY SPHERICAL AGGLOMERATION - - - - - - - 23

SILICA-INCORPORATED BRIQUETTES AS IMPROVED CHARGE FOR FERRO-SILICON MANUFACTURE - - - - - - - - - 24

CFRI SUGGESTS MEASURES FOR IMPROVED OPERATION OF BEEHIVE OVENS - - - - - - - - 25

POTENTIALITIES OF VIII SEAM OF JHARIA COALFIELD AS COKING COAL - - - - - - - - 26

CORRECTION FOR ADSORBED ACID IN THE CARBOXYL GROUP ESTIMATION OF COAL 26

NOTES & NEWS

COMMITTEE AND MEETING - - - 27

COAL SUPPLIES TO THE PROPOSED STEEL PLANTS AT VIZAG AND HOSPET - - - - - 30

TRENDS IN FUEL RESEARCH - - 32

HIGH GRADE STEELS MADE MORE CHEAPLY - - - - - - - - - 33

HYDRODESULPHURIZATION (HDS) PROCESS - - - - - - - - - 34

A NEW CRYOGENIC HYDROCARBON EXTRACTION PLANT - - 34

BIHAR GOVERNOR VISITS CFRI - - - - - - - - - - - - - 34

STAFF MATTER - - - - - - - 34

CFRI ABSTRACTS - - - - - - 36

Energy Resources Development in ECAFE Countries

FOR any developing country energy resources development should be a subject of major public concern and governmental policy decision. Effective use of fuel and power in the development of agriculture and industry would increase the overall productivity of the nation and is a major factor in raising the standards of living. Countries with greater consumption of energy *per caput* normally also have higher standards of living. In the formulation of energy policy a coordinated and comprehensive approach as against a loose collection of uncoordinated *ad hoc* and individual decisions in regard to mobilization of different sources and forms of energy can never be overemphasized. While reviewing the entire gamut of resources development of south Asian countries at the request of ECAFE, Dr A. Lahiri in a well-documented study entitled "An Approach to Cooperation in Resources Development in ECAFE Countries" has devoted a full chapter on fuel and energy resources development, which we reproduce in this issue of the *News*.

Among his various recommendations, Dr Lahiri has suggested that ECAFE may set up an organization for energy studies in the south Asian countries on the lines of Organization for European Cooperation and Development (OECD). He has rightly stated that such an organization must develop its own techniques for energy assessment and forecast for energy development, since the techniques adopted by the OECD countries are hardly applicable to the developing countries.

He has observed that a balanced energy policy must be based on an energy survey, a survey which should take into account "the resources and today's demands and requirements of tomorrow and the day after". It must take into account the potentialities and costs of utilizing national resources in relation to balance of payment position of a country and its ability to import energy. It is essential that projection should take into consideration the stage of development of any country, its social environment and economic programme, its

(*Continued on page* 8)

FUEL AND ENERGY RESOURCES DEVELOPMENT IN ECAFE COUNTRIES*

Domestic Energy Requirements

CIVILIZATION can be said to have begun from the day man learnt to grow corn from seeds and when Prometheus brought fire to the earth. Man, the 'predator' became a 'gregarious social animal'. If food is indispensable for human subsistence, energy is the basis of industrial civilization. Yet, as Putnam has remarked, hundreds of millions from Canton to Casablanca still cook their bare and meagre meals and heat their miserable mud and wattle hovels with farmyard wastes and dried animal dung. They also continue to use the most expensive form of energy today (in terms of calories required for feeding them and producing the necessary horse power), viz. muscle power and animal power. As both man and animal grow in their numbers and fuels for their 'muscle energy' become scarcer daily, they slide fast on the downgrade slope of impoverishment, stagnation and even starvation. The total man-power in terms of energy, for instance, of the whole of Indian subcontinent, can be equated to about 3-10 million tons of coal and its stock of more than 200 million heads of cattle will produce much less power with much lower efficiency than 65-70 million tons of coal. At 10 per cent efficiency, 200 million heads of cattle will want more than 1400 million wet tons of vegetable matter as raw material for energy generation and require 37 million acres of pastural agricultural land, if they were to be fed adequately. Ill-fed man or animal has much less average energy output. In many of the developing countries, however, the supply of simple and the bare essential requirements of domestic energy alone is presenting a gigantic problem and, if unattended to, can lead to catastrophies of unparalleled dimensions.

In many parts of these underdeveloped and developing countries, the major difference between man and animal is that the former eats cooked food. For the barest requirement of cooking two meals a day on an open grate stove with an efficiency not more than 10 per cent or so, the minimum requirement for a family of 5 persons will not be less than 100 therms per annum even in the rural areas and for urban population perhaps of the order of 300 therms per annum even in the tropical region. The urban requirement is equivalent to 2·2 tons of cowdung, or 0·7 tons of oil, or 850 cu. m. of natural gas, or 1775 cu. m. of coke-oven gas, or 1·2 tons of coal, or 1·9 tons of lignite, or 8790 kWh of electricity, or 1065 litres of kerosene per annum. It has been estimated that for the Indian Union, the coal equivalent of domestic energy for cooking alone is over 120 million tons per annum. Of these, 95 per cent is met today by farmyard wastes, viz. dung and wood. Appalling as these figures may appear, this equals perhaps 10-15 years' growth of wood in the uncultivated areas which is felled annually for fuel purposes alone.

However, much of what is burnt as fuel is unmonetized, whose amount can only be guessed. Statistics are difficult to acquire because of unrecorded nature of such pillage. Already, the natural balance between cultivated land and forest has been upset and this upset proceeds on at a faster rate than ever. Where such trade and commerce in wood, charcoal, dung, etc., are continued, the costs are also becoming prohibitive for the population. The consequent erosion of land and effect on climate with alternating droughts, aridity and floodings are recurrent features and are duly mourned over; but little is done about it. ECAFE should try to create a sense of urgency amongst the countries and their leaders by carrying out a survey of the requirements of domestic energy and the means of providing it on a countrywise and also on a regional basis for rural, urban and industrial areas and highlight the ravages and the waste that a policy of living on capital may lead to.

It has been stated that nearly 40 million tons of fertilizers will be annually required for the developing countries of the world only for preventing widening of the food gap with increase in population. It can be shown that even if the requirement of

*Excerpts from Dr A. Lahiri's communication to ECAFE Secretariat (1969).

solid fuels for rural population of India were supplied free of cost or subsidized and the farmyard waste, dung, etc., were put back to the soil and the trees and woods preserved, it will save annually several hundred million dollars worth of fertilizer, much of which at present has to be imported. It is common knowledge that mixed application of organic and inorganic nutrients yield better crops compared to the application of either.

Since by the end of this century, with the present rate of population growth, a person may not have more than a quarter of an acre of arable land available to feed him, it is essential that what is grown on the land be returned to it not only to prevent exhaustion of land but to reduce the enormous demand that will be made on fertilizers by permanently improving the status of the soil. There is also a growing and rival demand on the plant world for production of pulp and cellulose for the wherewithals of industrial civilization. They also lead to the annual depletion, though these requirements can perhaps be met to some extent by procurement from unhabited areas of earth or by 'tree farming'.

Many sources of energy have been suggested as substitutes for wood and farmyard manure for the less developed countries, but the problem remains. Any technology, any policy or any equipment which could avert this disaster is worth sponsoring, nationally and regionally. Perhaps a survey of the needs, resources and economics for production of energy for domestic purposes should be the first of the energy supply studies that should be undertaken by the ECAFE. The study should include assessment and survey of the ravages that may be caused by continuing the present policy quantitatively against given time scales.

Pooling of knowledge, devising of policies, drafting legislation, development of plant and equipment for production, distribution and use of domestic fuels for the developing countries must receive major attention. Alternative uses of such materials as are today burnt for fuel purposes must also be explored to make them economic assets to a community or a country.

Energy for Transport

Next in order of importance is the requirement of energy for transport. Again, there is the question of substitutes of both animate and inanimate non-commercial sources of energy for transport and distribution of goods by mechanized horse power for doing the same work. The inefficiency of animal power and its incompatibility with the needs for human requirements in populous developing countries with limited land have already been stressed. However, for planned development of transport and distribution of food as well as industrial raw material and products, an energy policy based on raw material resources of the nation, efficiency in use, requirement of and ability to earn foreign exchange must be taken into account.

The era of the old iron horse — the coal burning steam locomotive — of the railway is perhaps gone for ever in advanced countries. It still possibly has some residual use for the developing countries in regions where transport requirement and traffic density are yet not enough to justify use of other forms of traction. But where coal is not available, the relative claims for use of diesel power, electricity —whatever be its source — have to be carefully considered.

Often a quarter to a third of the total commercial energy requirement of a country will be in the transport sector. There is also the choice between traffic by road or rail and water. A study of the economics of transport over varying distances, load factors and capacities and nature of traffic and energy requirement for them are subjects of study which can be of great benefit to the developing countries. Alternative forms of transport for carrying of raw material, especially for ore, coal, gas, oil, etc., e.g. by pipeline, ropeways, etc., should also receive consideration. Since the form of transport (and the investment) will guide the requirement of energy (or energy-mix) for it, a study of the requirement of energy for the transport sector is intricately bound up with economics of transport itself. The Indian Railways have carried out exercises to establish criteria for electrification of tracks, dieselization and steam locomotion.

The ECAFE may appoint an Expert Committee and/or engage consulting engineers and economists to carry out a study of economics of transport and energy needs for the countries of the ECAFE region and especially those in the throes of development. Studies which may have been made by international bodies such as the World

Bank and other agencies should also be consulted and reviewed.

Long distance piping of coal, for example, was considered economic and competitive to rail transport before unit shuttle trains of capacity 10,000 tons or more were recently introduced in the USA. Piping of oil and gas over long distances is already undertaken but cost calculations, both for installation and operation for varying quantities and loads are not generally available. The exact economics of one country may not be applicable to another, but the relative consideration may be valid.

Energy for Industry

The need for primary and secondary forms of energy for industry — mining, metallurgy, chemical manufacturing, fabricating and other industries — is an equally important subject for study. The norm of requirement of fuels and efficiency of use vary from product to product, raw material to raw material, but an intelligent assessment of the needs of a country for 10-20 years has to be made in order that the resources may be planned and production of primary sources of energy — coal, oil shales, oil and natural gas — can be explored, produced and processed. Water power may also be considered in the same category.

Once the reserves and quality for primary energy sources are known, one has to assess the requirement of secondary forms of energy such as electricity, coke, processed or raw coal, oil refinery products and gas and to these now nuclear energy is to be added. Also, we still have the vast untapped sourece of energy in wind power, solar power, tidal power and in some areas geothermal energy.

The resources for energy are not evenly distributed, nor are their costs comparable in all countries and the latter is an important factor. As Prof. Thacker has remarked: "The prime goal is not to produce energy; the goal is to build the country." To achieve this end, both the cost and quantity of energy and the energy-mix and an energy plan based on sound technological and raw material assessment is a vital necessity for any developing country. "An energy balance sheet is necessary because needs of the people for useful energy are at the base of the entire energy-economy of a country. Only careful planning will avoid useless duplication (or dislocation) of energy needs."

The possibility of interconversion of energy by modern technological developments adds another dimension to changing nature and pattern of energy use. This calls for continuous assessment of the field by a team of experts and economists who are able to study, appreciate and project not only the changing pattern of energy use of the world, but assess the new possibilities.

New developments, such as in the field of fluidized combustion, may enable extremely low grade and low volatile fuels (up to 80 per cent ash) to be utilized with high efficiency and thus allow construction of economic thermal power plants on smaller scales for rural and scattered demand for low load factor areas more efficiently than conventional super-thermal power stations. Possibilities of MHD and EGD generation of power from thermal sources, development of coal or gas burning fuel cells, 'bulb groups' for harnessing tidal power, are factors of as much importance to developing countries as generation of nuclear power for areas devoid of fossil fuel resources.

"Each type of energy resource — conventional, non-conventional or nuclear — has its own specific field of application and the developing nations must learn from their mutual experiences rather than look to the more developed countries for advice and guidance in these matters. Many factors are, however, involved — climate, indigenous sources of energy, types of industry, skills and capital — which have to be considered for an Energy Development Plan. The output of human labour in both industry and agriculture is related closely to the horse power for each individual and this in turn is related closely to the capital investment. The ultimate limiting factor in the development of most countries is capital investment and in most of the less developed countries with great populations, the objective at each stage must be to give the optimum relation between the machine and man in the light of local conditions and employment." The use of energy itself stimulates industrial production and productivity and can transform an entire economy, and indeed a society, regionally or nationally, from that of a primitive food-gathering community

to centres of industrial prosperity and growth.

An energy survey must also estimate the phased requirement of capital required for developing energy sources of a country and compare it with alternatives or import or its substitution. The computation of energy balance is also "a consolidated account for all sources of energy, in which the several sources used in a particular area during a stipulated period of time are expressed in a common unit and brought together in a single table or curve. Fully developed, the energy balance traces each source of energy from origin to effective use, showing at each stage in this flow the physical and functional inter-relationship of the several energy sources". However, the consumption of energy has to be related to the consumers of energy and the resources of the country. Organization of collection of energy statistics in the developing countries is still rudimentary or even non-existent. No breakups usewise are generally available.

It is also necessary to have up-to-date and reliable figures and assessment for efficiency and cost generation and efficiency in use of energy based on various raw material resources. It may be true that for production of electricity, one ton of uranium is equivalent to 11,000 tons of coal, but often a ton of uranium-bearing rock considered to be economic today for extraction of uranium has less potential energy than a ton of average grade coal. On the other hand, even if coal is abundant, the load factors and capital investment in laying new tracks may justify electrification of an existing track rather than expansion of steam locomotion. "The fundamental objective of a country's energy policy must be to provide ample supplies of commercial sources of energy at the cheapest cost combination consistent with national interest."

In the less developed areas, foreign exchange is also a problem if import of energy is to be effected. The same holds true for equipment—coal mining machines, equipment for exploration, drilling and refining of oil and hydroelectric or thermo-electric plants. "In many areas, lack of foreign exchange has affected adversely the rapid development of energy resources. Policy in such cases will have to be guided by the various other considerations of national economy." ECAFE should prepare in collaboration with member countries not only an inventory but also the requirements and cost of supply of energy in various forms for the region for 20-25 years.

Intensive survey and exploration of indigenous resources for fuel is a primary necessity for the developing nations. Based on this knowledge, a fuel and energy policy can be conceived in the best national interests. In the ECAFE area itself considerable expertise exists and there is considerable scope also for exchange of energy sources. Coal and lignite of one area may be exchanged for oil in another. Oil and natural gas pipelines could be laid on a transcontinental scale. The Asian highway could also carry cross-country Asian electricity and natural gas pipelines. Tapping the vast resources of natural gas of the Middle East and perhaps of the SEA and its supply by overland route and, if necessary, by combining with sea routes may become a reality one day. Shipment of frozen methane from one country to another is already economic. Apart from the American example, the network of natural gas in USSR and East European countries is another example of economically viable establishment. The conveying of vast reserves of Sahara gas to Europe is being actively considered.

Indeed, in the field of energy resources there is a vast area for cooperation and collaboration in the SEA countries. International cooperation, however, presumes international amity, but basic economic interests may in themselves be a factor in creating such international cooperation.

Iron and Steel

Coking coal — Most of the countries in the ECAFE region are devoid or are short of coking coal resources. Yet many of them possess large reserves of non-caking coals or low rank immature coals such as lignite. Since solid fuels are still required in a major proportion for reduction of iron ore to the metal, this is another field in which the SEA countries may collaborate in providing a substitute for metallurgical coal or rather for coke.

The UN has published the details of many alternative processes for making iron and steel with other fuels than coke. Most of these, however, remain a commercial curiosity and the blast furnace is still considered the best technique for making iron. Major technological innovations are, however,

afoot both in the method of production of iron and steel and in preparation of solid fuels required for reduction in blast furnaces. Partial replacement of solid fuels with auxiliary fuel injection in blast furnaces is already established technologically; its economics varies from country to country and from plant to plant. It is likely that the most important commercial development in reduction of iron ore will be in the form of pre-reduction of pellets and its subsequent smelting in conventional blast furnace with 'synthesized' coke (formed coke) followed by direct conversion of pig to steel by oxygen spraying and continuous casting.

Formed coke — Production of iron and steel is inseparable from industrialization. For many developing countries, however, there is a temptation to export its best resources for earning foreign exchange; it is often of mutual advantage if the ore to be exported is smelted at home. Between the UAR and Japan, only India and Australia possess coking coal; the resources even in these countries are by no means abundant. India, on the other hand, possesses nearly 60 per cent of the world's total reserves of high grade iron ore and is a world exporter of this ore. The iron ore is scattered over many parts of the country, but coking coal is located only in one coalfield in mid-eastern India, Bihar. Methods have been developed in India for production of 'formed coke' based on non-coking coal on pilot plant scale for use in metallurgy. Investigations are being conducted to pelletize and pre-reduce ore pellets. A combination of the use of pre-reduced pellet and fluxed ash formed coke may lead to a saving of nearly 50 per cent or more in coke consumption. Technology may enable various types of fuels, including those of low rank and anthracites to be converted into coke suitable for standard metallurgical use. An additional advantage is that the process can use non-coking coal fines. Considerable development on a demonstration and industrial scale will, however, be required before such technology could be applied on a large scale in furnaces of capacities of 2500 tons per day. Technologically, the objective can be achieved, but its economic feasibility will depend on further development.

The formed coke technique is already being used on a commercial scale in Poland for production of foundry coke from low rank non-coking coals and trials have already been carried out with various types of formed coke for production of iron in low shaft furnaces at the OECD research centre at Leige. In many other countries (USA, West Germany, France, Belgium, Rumania, Japan and France), attempts are being made to prepare formed coke by one method or another and for varying uses. The ECAFE could commission an authoritative survey of these techniques. [The Central Fuel Research Institute (India) may be glad to do it.]

Pre-reduction of iron before smelting either in the conventional blast furnace or in an electric furnace or for production of sponge iron has to be studied on an adequate scale. Lignite, coal, low temperature coke, coke breeze, oil and natural gas have all been tried in different countries on different scale. The US Bureau of Mines have carried out intensive tests and a 25 tons/hour pre-reduction plant is now under construction for trials. The Steel Corporation of Canada, in collaboration with Lurgi at West Germany, has developed a technique for pre-reduction known as S-L Process. The processes are similar in nature, but their applicability to the various types of fuels and reductants has yet to be assessed and costs ascertained. A survey of the technology is another subject which may be sponsored by the ECAFE.

In view of the importance of iron and steel in national ecomomy for developing countries and of the scarcity of coking coal in ECAFE countries, a Regional Centre for Research & Development of Iron & Steel with non-conventional processes may be set up. The ECAFE countries should collaborate on a financial participation basis. It is a worthwhile project to be taken up with the Asian Development Council to be financed by the Asian Development Bank.

A project for setting up of a 250-300 tons/day blast furnace to be operated with formed coke is under consideration in India. Consulting engineers have already been appointed for preparing specifications and cost estimates for production of formed coke. Experimentation in blast furnace with normal or sized ore, pelleted ores and pre-reduced ores may be undertaken when such a plant is built. The ECAFE may consider supporting such a project. In exchange for financing, ECAFE may obtain the rights of processes developed and the

technology could be a property of the ECAFE for use by its member countries. India, Burma, Thailand, Indonesia, Philipines and Korea, and perhaps even Australia and Japan may be interested in this project. Middle eastern countries which have coal resources and ore, desirous of development of iron and steel technology (e.g. Iran), may also be interested.

Large quantities of iron ore are today exported to Japan from India from the Orissa coast. Large tonnage of export are being planned, which may amount to more than 20 million tons a year in the near future. This area also contains non-coking coals of sub-bituminous rank. Production of cheap iron in this area should, therefore, be of international interest in the ECAFE region. As in the case of OECD low shaft furnace experimentation centre, the individual countries interested in the project could become members by subscription and take part in the experimentation, both by sending their raw materials for trials and by deputing expert personnel to take part in the project. Others, such as Japan, could participate with supply and manufacture of equipment and in installation. [The Central Fuel Research Institute (India) which has taken a lead in the matter, could prepare a project for setting up of such a centre for R & D, if commissioned by the ECAFE.]

The basic process steps involved, viz. fluid bed carbonization, formed coke manufacture by oxy- or heat-curing, low shaft or small blast furnaces, pelletizing and prereduction technology, etc., are already available from different countries. Fluid bed carbonization plants operating on several hundred tons per day per unit are already in operation in the USA, UK and in some of the East European countries. A combination of these various techniques and processes designed to produce iron from low grade or beneficiated iron ores, iron dusts and with low rank non-caking coals at the cheapest cost of investment and production will be an achievement of significance which should benefit all the ECAFE countries and indeed even developed countries in the long run.

Conclusion

Thus, in the field of fuels and their utilization, the ECAFE may establish: (i) An Energy Survey Commission for the ECAFE countries which could study specific areas of energy consumption, especially for domestic, transport and agricultural requirements and also prepare energy forecasts for total energy-mix, regionally and nationally, in which each of the countries could participate by having a counterpart national organization for cooperation. In this connection, the report of the Energy Survey Committee set up in India with OECD experts may be studied. This report may constitute a prototype for initial studies in the ECAFE countries. The purpose of the Energy Commission should be to sponsor and organize countrywise energy survey and give such assistance through international expertise as may be needed or available. The study should cover energy resources, costs of energy generation, distribution and consumption. Such a Commission could also highlight problems of energy conversion such as conversion of coal to oil or to gas, production of synthesis gas, harnessing of energy from specific sources, both conventional and non-conventional, for further research and development at national or international level.

(ii) The Central Fuel Research Institute of India, Resources Research Institute of Japan and CSIRO of Australia are major centres for studies on fuel technolgy not only in the ECAFE region but in the world, equipped as they are with a variety of expertise, pilot plants and other laboratory facilities. Facilities of these institutions could be pooled for regional studies and preparation of feasibility reports for fuel utilization.

(iii) These institutions could also offer training facilities in fuel technology and with some help from the ECAFE (e.g. housing of students), one or more of these institutions could be organized for training. Already CFRI (India) is offering such facilities on a restricted scale to students in the ECAFE. (iv) Arising out of the fuel situation in the area as well as natural resource position and the importance of iron and steel in national economy, setting up of an R & D centre for production of iron with noncoking coal by advanced techniques should be another worthwhile project in which the ECAFE countries could collaborate under the auspices of Asian Industrial Development Council. Such a research centre would perhaps cost about $ 15-20 millions

in capital investment, but will be largely self-supporting in operation through sale of products and from national contributions.

(v) Specific fuel problems of any country could be taken up for investigations on a bilateral or multilateral collaboration basis. These fields involve combustion, preparation, beneficiation and briquetting of coals, production of domestic fuels by low and high temperature carbonization, gasification of coal for synthesis gas and town gas generation, solvent extraction and hydrogenation, studies on hydrocracking and hydrotreatment of heavy oils, beneficiation and processing of oil shales, studies of by-products of coal and lignite distillation, testing of mining equipment, training of fuel specialists, carrying out fuel efficiency studies, etc.

Such equipment, including pilot plant facilities, for testing and training are available in the region, in particular in India, Australia and Japan.

A LAHIRI

Energy Resources Development in ECAFE Countries —

Contd from page 1

geographical location and political set-up and ambitions. Formulation of methods of forecasting must not only deal with total energy demands but also with energy-mix and balance.

Dr Lahiri has further stated that the Energy Survey Commission for ECAFE countries could study specific areas of energy consumption, especially for domestic, transport and agricultural requirements and also prepare energy forecasts for total energy-mix, regionally and nationally, in which each of the countries could participate by having a counterpart national organization for cooperation. In this connection, the Report of the Energy Survey Committee set up in India may be studied and may constitute a prototype for initial studies in the ECAFE countries. The purpose of the Energy Commission should be to sponsor and organize countrywise energy survey and give such assistance through international expertise as may be needed or available. The study should cover energy resources, costs of energy generation, distribution and consumption. The Commission could also highlight problems of energy conversion such as conversion of coal to oil or to gas, production of synthesis gas, harnessing of energy from specific sources, both conventional and non-conventional, further research and development at national or international level.

There is an inherent flexibility in pattern of use of energy and the consumer can choose any of the numerous fuels available depending on the relative costs. Some of the forms of energy are interconvertible. Electricity can be produced from any of the several sources: coal, oil, natural gas, water power or nuclear fuels. Oil and gas can be produced from coal, though the costs differ considerably. An important consideration is the cost of transport of energy over a long distance; electricity can be transmitted over hundreds of miles and oil and coal can be transported to distant areas depending on the mode. Costs of transport vary widely and often decide consumer preferences. The costs of transport of natural gas, oil, electricity and coal in terms of heat energy increases in that order, but each has its own sphere of application. Nuclear energy will have an increasing role to play in future, but improvements in efficiency and costs of coal-based thermal power are also being continually effected which cannot be overlooked.

UTILIZATION OF WEAKLY TO SEMI-CAKING COALS OF MADHYA PRADESH

MADHYA Pradesh, located strategically in the centre of the country, is rich in mineral resources — particularly coal. Large tracts of coal, bearing areas, occurring mainly in the river valley systems of the Son, the Hasdeo and the Narmada, stretch across the State. The main coalfields are the Korba, the Sohagpur, the Chirimiri, the Bisrampur, the Pench valley, the Kanhan valley and the Singrauli. In recent years, extensive exploratory drilling has been undertaken in most of these areas and the total known resources of coal in the State have been assessed to be around 36,000 million tonnes, constituting nearly 28 per cent of the total reseves in the country. The reserves are widely scattered. A major portion of these coal resources are non-caking in nature having their chief uses as fuel for railway locomotives, for steam and power generation, cement making and the like. There are some deposits of medium to strongly caking coals in the western fringes of the Narmada valley coalfield. Besides, substantial reserves of weakly to semi-caking coals have been proved to occur in the Sonhat-Jhilmili region of the Sohagpur coalfield. In the context of the predominantly non-caking nature of coals in Madhya Pradesh, weakly to semi-caking coals of the Sonhat-Jhilmili area have significant regional importance. With this in view, the resources position and the utilization potentialities of weakly to semi-caking coals of Madhya Pradesh have been discussed in this paper.

Resources

Occurrences of weakly to semi-caking coals in the eastern part of the Sohagpur coalfield has long been known. The detailed proving of the coal resources has, however, been carried out only recently. The explorations so far completed have shown that sizeable deposits of economic value are available in the Churcha-Kutkona blocks of the Sonhat-Jhilmili region in the Surguja district of the State (Plate 1). The area is accessible by rail as well as by road. An all-weather road from Manendragarh to Ambikapur runs more or less along the southern boundary of the area. The Bijuri-Karonji branch line of the SE railway also runs to the south of the area, the nearest railway station being Baikunthpur Road for the Churcha block and Katora for the Kutkona block.

The Churcha block (lat. 23°19′-23°22′30″N, long. 82°26′-82°38′E) is situated in the south-eastern part of the Sonhat region. The drilling has proved the existence of only one workable coal seam designated as seam V. It records variation in thickness from 1·5 to 4 metres[1]. A new mine, viz. Churcha colliery has been opened up by the National Coal Development Corporation in 1965 for exploiting the coal resources of the seam. In the area so far developed, the seam has a thickness of around 3 metres but the working section at the colliery is restricted at present to the bottom 1·6-2·2 m thick portion only in order to maintain quality of coal to suit market requirements.

Kutkona blocks I and II (lat. 23°20′18″-23°22′30″N, long: 82°39′30″-82°44′30″ E) is situated in the western part of the Jhilmili region, about 14 km to the east of the Churcha colliery. The drilling in the area has proved the occurrence of 5 consistent coal horizons of which seam Nos. I and III are important for commercial exploitation[2]. The seam No. I (Kutkona seam), the basal coal horizon, records a thickness normally between 4 and 4·5 metres and the section is practically clean with occurrence of two to three dirt bands. The seam No. III (Chamat seam) maintains a thickness normally between 1·2 and 2·5 metres and its section is clean. In 1964, both the seams were touched through a pair of drifts and worked for a while. However, the mining has since been suspended due to sluggish market demand.

The total reserves for the seams are about 97 million tonnes, as shown below[1,2]:

		m tonnes
Churcha block	Seam V	39·70
Kutkona blocks I and II	Seam III (Chamat)	21·81
Kutkona blocks I and II	Seam I (Kutkona)	36·23
	Total:	97·74

SKETCH MAP OF SONHAT–JHILMILI AREA

SOHAGPUR C.F.

SCALE – 1 1/2 INCH = 1 MILE

GHUGRA

HASDO – R.

KATGODI

COLLY

CHURCHA

KUTKONA BLOCK I

KUTKONA BLOCK II

KUTKONA

BHASKARPARA BLOCK

BADSARA

JHUNKA N.

TO BIJURI

TO MANENDRAGARH

NAGAR

BAIKUNTHPUR R.S.

KATORA

PATNA

TENGNI

TO BISRAMPUR

INDEX

- FAULT
- DOLERITE INTRUSIVE
- BARAKARS
- TALCHIRS.
- METAMORPHICS
- ROAD
- RAIL
- BLOCK BOUNDARY

INDEX MAP

SOHAGPUR C.F.

HASDO R.

BHASKAR PARA

KUTKONA

TO BISRAMPUR

BAIKUNTHPUR R.S.

CHIRIMIRI C.F.

BIJURI

TO KATNI

ANUPPUR R.S.

TO BILASPUR

81° 30′ 82° 00′ 82° 30′ 83° 00′

23° 40′

23° 10′

23° 30′

25′

20′

15′

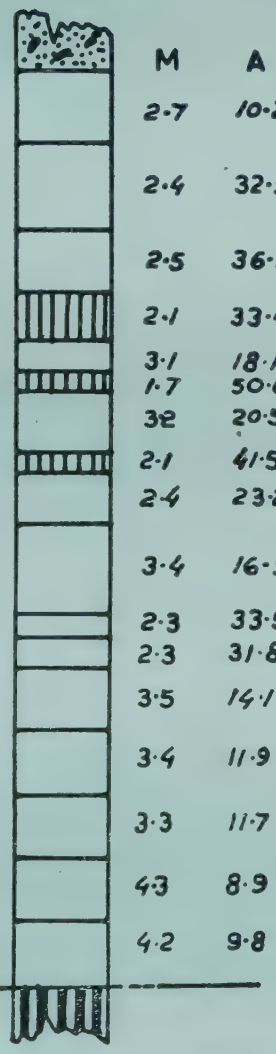
23° 10′

PLATE NO·2

SECTIONAL MAKE UP OF SEAMS AT CHURCHA - KATKONA AREA, SONHAT - JHILMILI REGION; SOHAGPUR C.F.

CHURCHA COLLIERY

SEAM V



T	M	A
0·35	2·7	10·2
0·43	2·4	32·5
0·30	2·5	36·5
0·24	2·1	33·4
0·14	3·1	18·1
0·08	1·7	50·6
0·31	32	20·5
0·09	2·1	41·5
0·24	2·4	23·2
0·46	3·4	16·9
0·07	2·3	33·5
0·16	2·3	31·8
0·30	3·5	14·1
0·30	3·4	11·9
0·30	3·3	11·7
0·30	4·3	8·9
0·30	4·2	9·8

KATKONA MINE

KATKONA SEAM

T	M	A
0·31	3·4	9·5
0·30	3·0	10·8
0·30	3·8	12·0
0·30	2·8	23·4
0·30	2·4	19·8
0·30	3·0	13·4
0·30	3·6	10·2
0·30	3·1	12·7
0·30	2·7	12·5
0·30	2·7	21·3
0·30	2·7	18·9
0·14	2·1	33·9
0·30	3·0	15·8
0·23	3·8	12·7

CHAMAT SEAM

T	M	A
0·36	3·6	20·5
0·30	3·3	19·4
0·26	4·7	15·1
0·21	3·0	27·4
0·30	3·3	23·3
0·22	4·9	12·5
0·30	3·8	14·6
0·30	4·9	12·1

INDEX

- COAL.
- SHALY COAL.
- SANDSTONE.
- SHALE.

NOTES:

- T — THICKNESS IN METRE.
- M — % MOISTURE ON 60% RH.
- A — % ASH ON 60% RH.

PLATE 2

The typical log sections of these seams together with quality of the coals from the seam subsections are presented in Plate 2.

Coal Properties

The properties of the coals from the important seams are given in Tables 1 and 2. The yields of products obtained from the laboratory scale low temperature carbonization assay are shown in Table 3.

The coals from all the seams are mostly fair in quality with 14-19 per cent ash and 2·5-3·5 per cent moisture on 60 per cent RH at 40°C basis. The coals from the present working section at the Churcha colliery are a shade better in quality analysing 14-15 per cent ash. The coals are weakly to semi-caking in nature with caking indices ranging normally between 9 and 14. The yields of tar are attractive, being 100-110 litres per tonne of dry coal and the coke types are moderate. The coals are particularly low in phosphorus, usually below 0·005 per cent.

Utilization

The weakly to semi-caking coals of the Churcha-Kutkona area have their obvious

TABLE 1 — QUALITY OF CHURCHA-KUTKONA COALS

Area	Seam	Particulars	On 60% RH at 40°C							Caking index
			Moist %	Ash %	VM %	FC %	Calorific value kcal/kg	Calorific value B.Th.U./lb	Total sulphur %	
Churcha	V	Working section	3-4	13·5-14·9	28·3-29·1	52·8-54·8	6675-6865	12,020-12,360	0·6-0·9	11-12
		Seam	2·5	18·9	26·2	52·4	6455	11,620	0·9	11
Kutkona	Chamat	Seam	4·0-4·1	16·7-18·2	28·4-29·4	49·4-49·8	6320-6445	11,370-11,600	Around 0·7	12-13
	Kutkona	Working section	3-3·5	14·4-16·7	27·0-27·4	52·9-55·1	6505-6675	11,710-12,020	Around 0·7	11-12
		Seam	3·0	16·1	27·7	53·2	6570	11,820	Around 0·7	11

TABLE 2 — PROPERTIES OF CHURCHA-KUTKONA COALS

(Dry mineral free basis)

Area	Seam	VM %	Calorific value kcal/kg	Calorific value B.Th.U./lb	Carbon %	Hydrogen %	Nitrogen %	Sulphur (org) %	Oxygen %
Churcha	V	33-35	8325-8430	14,990-15,120	85·2-86·4	5·0-5·1	1·7-1·8	0·2-0·4	6·5-7·7
Kutkona	Chamat	34·4-35·8	8315-8340	14,970-15,010	85·8-86·1	5·1	1·6-1·7	0·5-0·7	6·5-7·0
	Kutkona	32·4-32·9	8280-8365	14,900-15,060	86·2-86·5	4·9	1·6-1·7	0·4-0·6	6·5-6·6

TABLE 3 — RESULTS OF GRAY-KING LOW TEMPERATURE CARBONIZATION ASSAY AT 600°C IN RESPECT OF CHURCHA-KUTKONA COALS

(Per tonne of dry coal)

Area	Seam	Particulars	Coke (kg)	Tar (litre)	Liquor (litre)	Ammonia (kg)	Gas at STP (cu.m.)	Coke type
Churcha	V	Working	779-785·5	111·5-117·5	35·0-40·0	0·8-0·9	82·7-89·7	C
Kutkona	Chamat	—	781·5	112·5	41·5	1·1	85·1	C
	Kutkona	—	789·0-791·5	108·5-111·5	35·0	0·8-1·2	82·8-83·4	C

use as a blend for metallurgical coke making at the nearby Bhilai Steel Plant. Following the investigations carried out at the Institute[3], a portion of the Churcha coal is being used as a blend at the Bhilai coke ovens. This demand amounting to an average of about 12,000-14,000 tonnes per month provides outlet for a little less than half of the current production of the colliery. With the existing blending facilities at Bhilai, there are little prospects of increase in this demand. Necessarily, the rest of the output from the colliery has to be marketed chiefly as locomotive fuel and for other combustion purposes which certainly is not the proper use of such coals. For use in a coking blend, the ash in coal has to be maintained within a stipulated limit and for this purpose the seam is being worked through sectional mining restricted to the bottom 1·6-2 metre portion. But this sectional mining is endangering a large part of the coal reserves which will later be of not only high ash but more difficult and costly to extract, if not lost.

The use of these coals for low temperature carbonization industries to make semi-coke for domestic and industrial purposes is another possibility[4]. Technically, the sized (75-25 mm) non-caking coal can also be used for the purpose. But unfortunately, most of the non-caking coals in this region are high moisture, high oxygen, sub-bituminous coals which are very prone to weathering and undergo size degradation on heating producing undersize materials. Besides, the semi-coke prepared from such coals, being not so strong, undergoes substantial size degradation during handling and transport to consumer's end. It is here that the use of weakly to semi-caking coals offer a distinct advantage. Large scale low temperature carbonization tests carried out at the CFRI prototype plant of full commercial dimension have shown that excellent semi-coke of requisite physical strength, to withstand handling and transport over long distances, can be prepared from Churcha-Kutkona coals for domestic and industrial purposes[4]. The tar can be suitably processed to obtain valuable by-products such as phenols, cresols, xylenols, etc. However, since this conventional process is based on the use of sized (75-25 mm) coal only, the problem still remains about the disposal of almost an equal quantity of slack coal produced during mining, crushing and sizing. This constitutes a major bottleneck for any large-scale project of this nature.

In case it is desired to prepare only the domestic coke to meet local demand, the CFRI process of continuous devolatilization of coal using a travelling grate stoker can be employed. Such plants require only low capital investment and units of small to medium capacity can be installed at the consumers' sites. But even here, the problem of slack coal utilization remains. Since no recovery of byproduct is possible in the process, it is particularly applicable for inferior or sub-hydrous coals which normally have low tar yields.

Formed Coke

Our reserves of prime coking coals are, however, not only limited but also localized in the Bengal-Bihar coalfields. This has been an inhibiting factor in the expansion and the balanced regionwise development of the steel industry. The researches at the Institute, as elsewhere, were therefore, directed towards obtaining from non-caking coal, a product to serve as a substitute for hard coke. These efforts at the Institute have resulted in evolving what has since come to be known as "CFRI Formed Coke Process"[5]. The process primarily involves fluid bed carbonization of crushed coal (mostly below 3 mm) to obtain powdered char, tar and lean gas. The tar is suitably processed into a binder. The char and the binder along with the fluxes, if desired, are then mixed in requisite proportions and briquetted into desirable shape and size in conventional briquetting plants. The green briquettes are hardened in an oxidative heat treatment furnace to obtain a synthetic hard moulded product suitable for domestic and industrial purposes. The non-caking slack coals can also be used for the purpose provided the yields of tar are adequate to serve as a binder. But most of the non-caking coals of MP, being sub-hydrous in nature, are low in tar yields. It is against this background that the Churcha-Kutkona coal with their good tar yields are perhaps most suitable for the purpose.

An Integrated Scheme

From the above discussion. it is evident that weakly to semi-caking coals of the Churcha-Kutkona area offer scope for use in

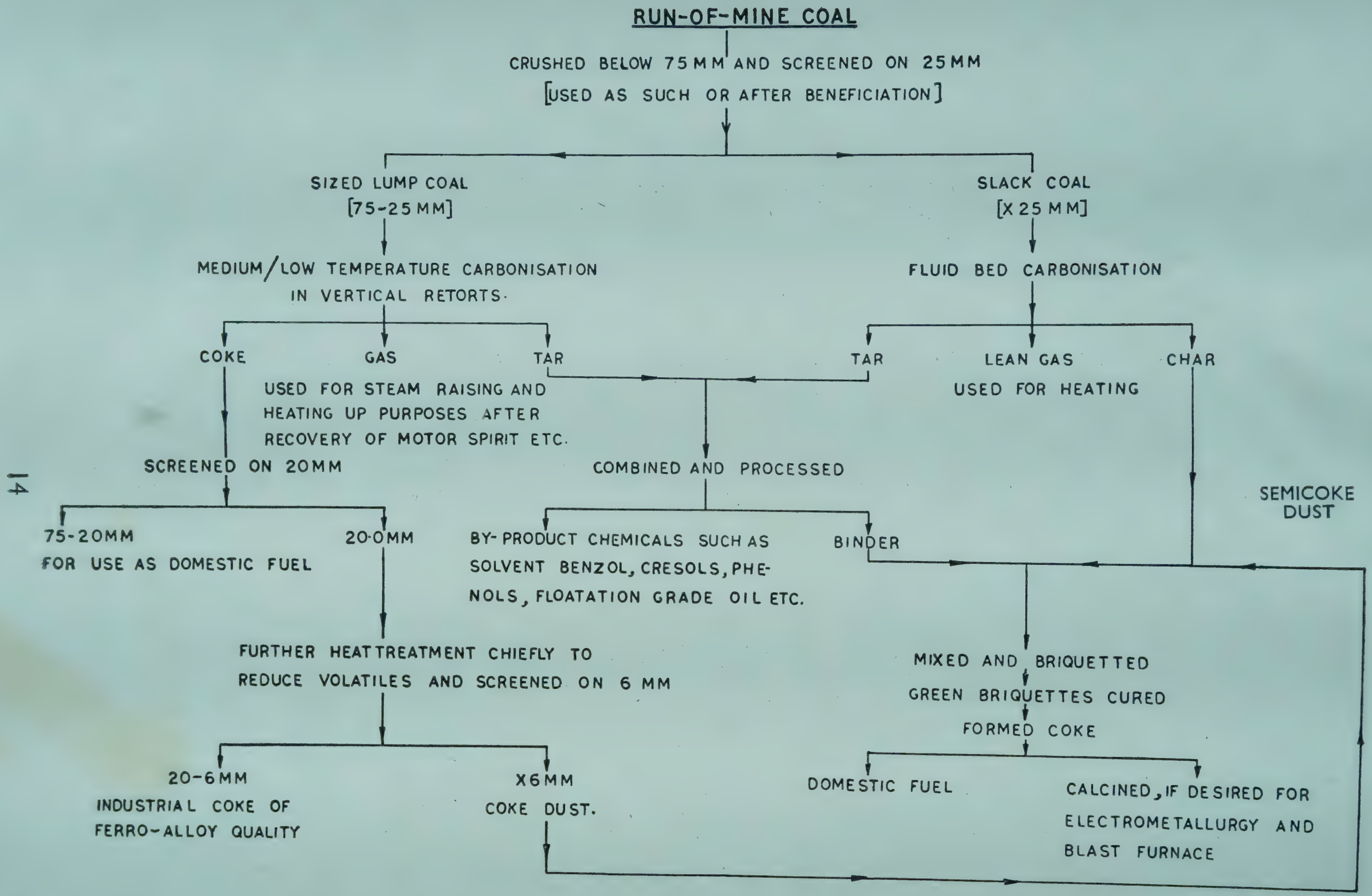


PLATE 3 — FLOWSHEET OF PRODUCT PATTERN FOR AN INTEGRATED PROJECT BASED ON SEMI-CAKING COALS OF CHURCHA-KUTKONA AREA

both the prototype low temperature carbonization plant and by formed coke process. If, however, the whole coal (after crushing below 3 mm) is used for formed coke process, almost the entire quantity of tar would be required to serve as a binder, thus depriving the project of substantial financial returns from valuable byproduct, chemicals, besides the advatage of the lump sizes which can straightway be carbonized in the CFRI prototype plant with byproduct recovery. The integration of the two processes can give maximum advantage. Such an integrated scheme for processing Churcha-Kutkona coals is outlined in the flowsheet given in Plate 3.

The scheme envisages the crushing of the r.o.m. coals, as such or after suitable beneficiation, to below 75 mm and screening on 25 mm to obtain 75-25 mm lump coal and ×25 mm slacks. The sized coal (75-25 mm) may be processed in the CFRI continuous vertical retorts under medium/low temperature carbonization conditions to produce coke, tar and gas. The coke is to be screened at 20 mm. The 75-20 mm sized coke having about 10 per cent volatile matter would be an excellent smokeless domestic fuel. The ×20 mm coke can also be further devolatilized in a shaft furnace, followed by screening, to yield 20-6 mm sized industrial coke with varying volatile matter to meet market specification for ferro-alloys, ferro-silicon, calcium-carbide, etc. The ×6 mm coke dust can be mixed for processing with the fluid bed char.

The slack coals (×25 mm) will be crushed below 3 mm and subjected to fluid bed carbonization to obtain char, tar and lean gas.

The tar from both the sections is combined for processing to obtain different fractions. The light and middle oil fractions may be processed to yield certain chemicals such as solvent benzol, cresols, phenols, xylenols, creosote oil, flotation grade oil, etc. The heavy oil fractions will be treated to obtain the binder necessary for the production of 'green' briquettes.

The fluid bed char is thoroughly mixed with the tar binder in desired proportions and briquetted to the required shape and size. The 'green' briquettes are cured in an oxidative heat treatment furnace to obtain formed coke which can straightway be used as a domestic fuel. The formed coke, if necessary, can be further calcined, chiefly to reduce volatile matter, to suit special uses such as electro metallurgy (ferro-manganese, ferro-silicon, ferro-chrome, etc.) and for blast furnaces in iron metallurgy. As the formed coke is produced 'synthetically', its physical properties can be controlled to an extent and thus it is tailor made to the requirements. A comparative statement showing the properties of the retort coke and the formed coke obtained from Kutkona coals is given in Table 4.

TABLE 4 — COMPARATIVE PROPERTIES OF SEMI-COKE AND FORMED COKE FROM CHURCHA-KUTKONA COALS

Particulars	Semi-coke	Formed coke
1. *Proximate analysis*		
Ash %	25	<25
Volatile matter %	<3	<3
2. *Sulphur* %	0·3	0·3
3. *Phosphorus* %	0·02	0·02
4. *Calorific value, kcal/kg*	5850	—
5. *Screen analysis % cum.*		
+25 mm	66	—
−13 mm	86	—
6. *Bulk density, kg/m³*	580	600
7. *Porosity* %	44	43
8. *Shatter values, % cum.*		
on 36 mm	—	98·0
on 25 mm	81	—
on 13 mm	94	98·8
9. *Micum value, % cum.*		
on 40 mm	—	86·5
on 20 mm	73	—
on 10 mm	82	—
×10 mm.	18	12·0
10. CAB value, ft³/min. of dry air at STP	0·023	—
11. Point strength, kg	—	400

The gas from both the sections will largely be utilized in the plant for steam raising and heating. With a high capacity plant and its integration with blast furnace, the entire gas from the vertical retorts can be used for synthesis of chemicals or fertilizers.

Disposal of Products

The major product is obviously the coke. The 75-25 mm sized lump coke from the retorts and the formed coke may find use as excellent smokeless domestic fuel. The market survey and the cost assessment made by the Institute show that the domestic coke produced from the Churcha-Kutkona area can be sold with advantage up to distances of 1000 km or even 1500 km.

Not only the major townships and urban areas of MP and eastern Maharashtra but also the extensive and thickly populated fuel scarcity areas in the upper Gangetic valley, Rajasthan, and areas up to Delhi in the north, Bombay in the west and perhaps to Vishakapatnam in the south can be the market for this fuel.

The 20-6 mm sized coke from the retorts with its low volatile content of about 2-3 per cent can be used in ferro-alloy, ferro-silicon and calcium carbide industries. The low phosphorus content of the coke is a particularly desirable point. If desired, the formed coke of required strength can be further calcined to obtain ' hard coke ' suitable for iron metallurgy in blast furnaces. The basic chemicals such as solvent benzol, xylenol, phenol, cresols, etc., which are in demand in the country, shall find ready market bringing handsome financial returns to the project.

Conclusion

Sizeable deposits of weakly to semi-caking coals have been proved to occur in the Churcha-Kutkona area in Surguja district of Madhya Pradesh. These coals offer scope to promote industrial development in the region. The laboratory and pilot plant investigations at the Institute show that there are favourable prospects for setting up an integrated project, comprising a battery of the " CFRI Prototype Continuous Vertical Retorts " to carbonize lump coals (75-25 mm) and a ' Formed coke ' plant to process the slack coals ($\times$25 mm) to obtain coke for domestic and industrial purposes, besides valuable byproduct chemicals.

Such an integrated project to process initially about 1500 tonnes/day of Churcha-Kutkona coals will be technically feasible and economically viable. The project will pioneer the ' Formed coke ' process in India, which has great scope of application not only for industrial development in MP but also in Maharashtra, Andhra Pradesh and other contiguous coal-bearing areas for production of domestic and metallurgical fuels. Of even greater importance of the project is the possibility of finding solution to the problem of extraction of iron in India without the use of coking coals. Besides the diversification in uses, it may also solve the major problem of utilizing small coals (slacks) and coal fines which today constitute a bottleneck in the development of coal resources of Central India. Thus the setting up of an integrated project, based on weakly to semi-caking coals of Churcha-Kutkona area, for production of smokeless domestic fuels and industrial grade coke by employing both the vertical retort technique and the CFRI ' formed coke process ', deserves special consideration. At the request of the MP Audyogic Vikas Nigam, the CFRI had prepared a Project Report for carbonization of 1500 tons/day of Churcha/Kutkona coals, and the NCDC are contemplating setting up of a Formed Coke Plant based on the Churcha slack for which M/s Chemicals & Metallurgical Design Co. (P) Ltd. have been appointed as consultant. In view of the scarcity of domestic fuel in western and north-western India, these projects offer investment opportunities both for public and private sector bodies.

B. S. Deshmukh & A. K. Moitra

References

1. Interim report on prospecting for coal in Churcha area (Sonhat B & C Blocks), Sonhat coalfield, Dist. Surguja (MP) (NCDC Ltd.), Nov. 1962.
2. A preliminary geological report on Kutkona block II, Jhilmili coalfield, Surguja Dist. MP (NCDC Ltd.), July 1964.
3. Moitra, A. K. *et al.*, " Carbonization potentialities of Churcha coal, Jhilmili coalfield, MP ", *FRI News* (1967), **17** (2) 66-71.
4. Low to medium temperature carbonization potentialities of Churcha-Kutkona coal of Jhilmili coalfield (CFRI unpublished work).
5. " On the process for the production of hard briquette cokes and moulded shapes from non-coking coals, coke breeze and the like suitable for domestic and/or metallurgical purposes ", *Indian Patent* 99655, 1966.

NATURAL COKE (JHAMA): ITS PROPERTIES AND POTENTIALITIES

Introduction

INTRUSION of igneous rocks in coal seams is a common feature of Indian coalfields. The two common intrusives are mica-peridotite and dolerite. These occur generally as dykes (wall) or sills, the dyke traversing the coal seam at an angle as a wall and the sill generally running parallel to the bedding plane. Mica-peridotite, because of its chemical nature, attains high fluidity during its molten state and, therefore, may cause extensive damage to the coal being often present as thin veins which permeate the seam at different bedding planes. The damage is far less in the case of dolerite because of its higher viscosity. The damage is mostly localized.

The coal is altered to 'natural coke' or 'jhama' along its contact zone with the intrusive rocks, the carbonization effect slowly and progressively decreasing away from the contact. The pyrolysis by the intrusives takes place *in situ* under pressure and the resulting coke is dense, close textured and hard. The amount of coal so affected depends on the nature (mica-peridotite or dolerite) of the intrusives, their thickness and geological characteristics of the affected strata. The Barakar Measure coals are the most affected by the intrusives. Due to the difficulty of mining such a hard material and having unknown industrial use, at present, deposits of jhama are only mined to the extent that mining of the coal demands. Large amount of deposits of jhama (estimated to be about 400 m tons by C. Fox) are thus left unextracted. The possibility of utilization of the natural coke in industries is, therefore, worth serious consideration.

Before the jhama can be commercially utilized, it is necessary to assess its physical and chemical properties and also to carry out exploratory commercial tests. From the nature of the formation of jhama, it implies that in the same deposit there will be a gradation of properties. From hard coke in the contact zone the properties will approach and ultimately become that of the unaffected coal. The uniformit and consistency of properties of jhama in a deposit, which is essential for a commercial raw material, may thus be restricted to a comparatively small volume of the coal affected. An assessment of the amount of the material having properties within acceptable limits of variation is essential before its utilization in industry can be planned.

Prior to 1960, no organized efforts appear to have been made to assess the physical and chemical properties of a deposit of jhama and judge its potentialities by commercial tests. In that year at the instance of CFRI, a sample of jhama from XV seam at Digwadih colliery, Jharia coalfield, was assessed for its physical and chemical properties in the laboratory and later exploratory tests in pilot and commercial cupolas were carried out on bulk samples. The results indicated that the particular jhama could replace the hard coke used in a 'split charge'. Laboratory investigations on samples from another deposit from X seam of the Jharia coalfield indicated their suitability for use in commercial cupolas But the investigations had to be abandoned as commercial tests could not be carried out due to non-availability of bulk samples needed for the tests.

The available information on physical and chemical properties are collated in this note so that these may be drawn upon in future, when the utilization of jhama is contemplated.

Quality

The changes in the properties of coal from a seam (Barakar measure, Raniganj coalfield) affected by a sill was clearly brought out by a study carried out at the Raniganj CSL.

The coal is generally medium to strongly caking with volatiles (d.m.f.) in the range of 32-35 per cent. The volatiles have dropped to 5·1 per cent within 0·10 m of the contact zone and progressively increases away from the contact. Beyond this the coal retains some of its caking properties

TABLE 1 — QUALITY AND PROPERTIES OF JHAMA FROM DIFFERENT COALFIELDS

		Ranigang (*Qr. Jr.* GMMS, Sept. 1968, 141)	Jharia (X, IX/X, XIII and XV seams)	E. Bokaro	S. Karanpura	Madhya Pradesh (Majhan, Sohagpur, seam I)	Maharastra: Ambara seam III Pench-Kanhan	Maharastra: Pathakhera
	Moisture %	1·2-2·3	1·5-2·1	0·9-4·6	0·6-3·1	1·5	1·6	1·2
	Ash %	27·7-32·7	21-35	23-31	24-37	12·9	24·2	21·7
	Phosphorus %	0·112-0·380	0·076-0·366	—	—	—	—	—
d.a.f. basis	Volatiles %	5·1-12·0	5·6-15·7	5-30	10-11	18·7	27·1	24·3
	C.V. kcal/kg	8040-8290	7775-8365	—	—	8450	8630	8810
	Carbon %	90·3-95·4	88·7-94·9	—	—	89·0	88·5	90·0
	Hydrogen %	1·5-3·7	1·4-4·3	—	—	4·4	5·0	4·8
	Sulphur %	—	0·57-1·37	—	—	0·5	—	0·7
	Nitrogen %	—	1·43-2·10	—	—	1·8	—	1·9
	Oxygen % (by diff.)	—	1·59-5·24	—	—	4·3	4·3	2·6
	Caking index	Non-caking	Non-caking	—				
	GK (600°C) assay			Coke type: C-A		Coke type: inferior to C tar: 89 lit./ tonne	Inferior to B tar: 62·5 lit./tonne	D

TABLE 2 — PROPERTIES OF JHAMA FROM DIFFERENT DEPOSITS IN SOME WORKING COLLIERIES OF THE JHARIA COALFIELD

Colliery (seam)	Pure Chasnala (IX/X)			Angarpathra (X)		Asha-kuti (XIII)	Bene-dih (XIII)	Dig-wadih (XV)	Hard coke-			
	Top	Mid.	Bot.	I	II				I	II	III	IV
Moisture %	2·1	2·1	1·5	1·7	1·7	1·6	1·9	2·0	3·2	0·8	0·5	0·6
Ash %	20·9	21·4	23·8	35·3	24·7	25·6	27·5	19·4	19·9	24·2	12·7	24·0
Volatiles %	4·1	8·2	11·7	3·5	5·8	8·8	10·4	9·6	2·8	1·2	0·5	1·1
Phosphorus %	0·319	0·366	0·252	0·412	0·244	0·118	0·076	0·173	0·159	—	0·028	0·153
Cal. val. (kcal/kg)	6000	6185	6250	4935	6085	5865	5845	6575	6183	—	—	5944
d.a.f. basis												
Volatiles %	5·3	10·7	15·7	5·6	7·9	12·1	14·7	12·2	3·6	1·6	0·6	1·5
Carbon %	93·2	90·8	88·9	94·9	92·5	90·2	89·5	88·7	95·8	98·5	97·8	96·9
Hydrogen %	1·8	3·4	4·3	1·4	2·6	3·0	4·2	3·4	1·5	0·8	0·6	0·6
Sulphur %	0·79	0·99	1·02	0·65	1·28	1·29	1·37	0·57	0·8	0·5	0·7	0·7
Nitrogen %	1·43	1·91	2·09	1·46	1·73	1·69	2·10	2·09	1·5	0·5	1·1	0·9
Oxygen %	2·78	2·90	3·69	1·59	1·89	3·82	2·83	5·24	0·4	—	—	0·9
HGI	37	51	72	45	40	51	75	71	—	—	—	—
Reactivity (to CO_2)	150	158	150	—	—	152	140	138	—	—	—	—
Fusion temp. of ash (°C)	1080-1320	1090-1360	1120->1400	—	—	1050-1300	1080->1400	1130-1220	—	—	—	—
Shatter index												
$+1\frac{1}{2}''$	—	—	—	89·8	84·7	—	92·1	—	—	—	—	—
$+\frac{1}{2}''$	—	—	—	97·6	95·9	—	98·0	89·7	—	—	—	—
Micum index												
M_{40}	—	—	—	73·8	69·8	—	50·7 (small)	65·0 [$+\frac{1}{8}''$]	—	—	—	—
M_{10}	—	—	—	10·8	18·0	—	27·1 (small)	[abra-sion index]	—	—	—	—

and further towards roof the coal is unaffected. The high phosphorus in the sections affected is noteworthy.

The quality and properties of jhama both from near surface and at depth from different coalfields of India have been shown in Table 1. The large variation in volatile matter yields and phosphorus, carbon and hydrogen (where data are available) in different deposits is quite evident.

The detailed chemical and physical properties of jhama from different deposits in the Jharia coalfield both near the surface (Table 2) and at depth (Table 3) are given. Table 2 also contains data for manufactured hard coke for comparison.

Very high phosphorus in the first two deposits may be noted. The variation of the physical and chemical properties of the jhama from the Top, Middle and Bottom sections at the first colliery is evident. The comparatively lower fusion temperature of ash, high reactivity (to CO_2) and high shatter index are also noteworthy.

The chemical composition of the intrusive rock and ash from jhama has been given in Table 4 which also contains that of coal for comparison. The large amounts of iron, calcium and magnesium, phosphorus and alkalies in the ash from jhama are to be noted. Comparatively higher phosphorus in the jhama in relation to the parent coal from XV seam (Digwadih) is evidently due to enrichment from intrusive rocks. It is considered that the highly phosphatic intrusive rock might have penetrated the jhama as thin veins. Also, the high temperature (of the order of 600-900°C) of the magnetic rock might have

TABLE 3 — QUALITY AND PROPERTIES OF JHAMA FROM JHARIA COALFIELD AT DEPTH (FROM BOREHOLE CORES)

	Sudamdih				Monidih		
Seam	XVIII		XVI	XV	XIV	XIII	XII
(depth from surface) (m)	92·0		(420)	(220)	(549)	(699·5)	(718)
	I	II					
Moisture %	1·4	1·8	1·2	1·5	0·7	1·1	1·4
Ash %	29·4	29·3	27·9	22·8	29·5	27·3	31·0
d.a.f. basis							
Volatiles %	8·8	11·3	9·4	5·2	5·7	4·6	8·4
Carbon %	92·63	90·75	92·73	94·68	95·63	95·32	91·33
Hydrogen %	1·92	3·15	2·72	1·68	1·22	0·96	1·12

TABLE 4 — CHEMICAL COMPOSITION OF DYKE AND ASH FROM JHAMA AND COAL

	Dyke (associated with coal seam)		Jhama				Coal
	Mica-peridotite	Angarpathra colliery	X seam (+75 mm) at Angarpathra	XV seam at Digwadih	XIV seam Monidih, borehole	XVIII seam Sudamdih borehole	XV seam at Digwadih
SiO_2 %	27·8-34·9	40·68	56·92	43·88	52·38	54·16	46·64
Al_2O_3 %	7·3-11·4	7·67	21·24	21·53	17·15	22·67	23·26
Fe_2O_3 %	1·0-4·7	15·49	4·25	9·38	7·78	6·09	10·33
TiO_2 %	3·0-4·3	7·40	1·80	1·15	1·40	1·50	1·55
CaO %	5·5-10·0	7·75	2·83	2·04	4·20	4·73	7·60
MgO %	8·8-16·9	11·85	1·69	8·96	8·41	3·05	4·89
P_2O_5 %	3·5-4·8	5·39	1·71	4·96	1·17	1·94	0·86
SO_3 %	0·01-0·13	0·84	0·21	4·35	0·73	0·75	4·29
Alkalies & (errors) %	3·1-5·7	2·93	9·35	3·75	6·78	5·11	0·58
Fusion temp. of ash °C	—	—	—	1130-1220	1125-1165	1190-1260	1180-1225

caused breakdown of the phosphorus-bearing minerals in presence of hot coke and the phosphorus might have combined with the breakdown products of other minerals present in coal. The lowering of the silica in the jhama is to be noted and might indicate formation of the volatile fluoride of silica in the hot jhama zone.

Size Degradation on Storage

Jhama is reported to undergo a size degradation during storage in stacks. Two bulk samples (about 3 tons each) of lump size from X seam of the Jharia coalfield were stacked in the laboratory site and the size consist analysis carried out periodically, over a period of about 8 months. The data given in Table 5 indicate a decrease of 6·5-9·6 per cent in the +7·5 cm sizes with a consequent increase in the intermediate sizes.

Commercial Tests

The results of the tests carried out in 1 ton and 5 ton cupolas by the NML is contained in their report [RR No. 176/64] and the relevant tables are reproduced in this paper. Screen analysis of jhama samples used for cupola tests is given in Table 6. In Tables 7 and 8, the chemical and physical properties of the jhama have been compared to manufactured hard coke usually used in industrial cupolas. In Tables 9 and 10 the quality of pig iron and slag produced during the trials have been given.

The conclusions arrived at from the results of the tests were that the jhama could not fully replace hard coke normally used in industrial cupolas, but the 'split charge' could be entirely of jhama, thus totally replacing hard coke, the bed

TABLE 6 — SCREEN ANALYSIS OF THE JHAMA SAMPLE (PREPARED FROM XV SEAM OF DIGWADIH COLLIERY) USED FOR CUPOLA TESTS

Size (mm)	Wt %
+50	72·00
−50+25	11·90
−25+12	5·80
−12+6	3·90
−6+3	3·70
Below 3	2·70

TABLE 5 — SIZE DEGRADATION OF JHAMA ON STORAGE

(X seam at Angarpathra colliery)

Size (cm)	Sample I			Sample II		
	Initial	After 88 days	After 208 days	Initial	After 90 days	After 202 days
+7·5	39·07	35·54	32·54	55·31	49·55	45·71
−7·5+2·5	41·07	42·65	44·00	21·52	24·28	24·57
−2·5+1·25	10·40	11·22	13·37	9·54	10·91	14·11
−1·25	9·46	10·59	10·09	13·63	15·25	15·61

TABLE 7 — PROPERTIES OF JHAMA (XV SEAM, DIGWADIH) AND FOUNDRY (HARD) COKE

	Moisture %	Ash %	Volatiles %	Fixed carbon %	Sulphur %	Phosphorus %
Hard coke	1·15	23·9	2·5	72·45	0·4-0·6	0·30
Jhama	2·5	15·7	10·8	71·0	0·5	0·135

Composition of ash

	SiO_2 %	Al_2O_3 %	Fe %	CaO %	MgO %
Hard coke	54·0	28·7	5·0	3·04	1·95
Jhama	48·8	34·2	4·1	3·40	4·70

TABLE 8 — PHYSICAL PROPERTIES OF HARD COKE AND JHAMA

Properties	Hard coke	Jhama
Shatter index, $+\frac{1}{2}''$	82·10	89·70
Bulk density	1·28	1·35
Abrasion index ($+\frac{1}{8}''$)	76·90	65·00
Reactivity to CO_2	145	138
Specific gravity,	2·2	3·2
Porosity %	40	10
Calorific value, B.t.u./lb	11,500	12,400
Crushing strength (under constant load at 6 and 10 kg at temp. up to 600°C)	Did not develop any crack till 600°C	Slight crack at a load of 10 kg between 590° and 600°C

[From RR No. 176/64, " Coupola operation with jhama coal as a substitute for foundry coke ", Jatinder Mohan, J. Goswami, A. B. Chatterjee & B. R. Nijhawan.]

TABLE 9 — ANALYSIS OF PIG IRON USING 100% HARD COKE AND 100% JHAMA, AS SPLIT CHARGE

Fuel	Temp. of molten pig iron °C	Chemical analysis of pig iron C %	Si %	S %	P %	Mn %
100% hard coke as charge	1280	2·5	4·3	0·03	0·42	0·26
100% jhama as charge	1280	2·6	4·2	0·05	0·44	0·30

Analysis of slag

Fuel	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %
100% hard coke	34·5	19·3	24·9	19·1	2·1
100% jhama	43·44	22·07	5·13	24·64	4·41

charge being still required to be of hard coke. The results of these tests, therefore, indicated the possibility of partial replacement by jhama of hard coke required in foundry operations.

Tests carried out at the National Metallurgical Laboratory with jhama in low shaft pilot plant for production of pig iron showed extremely irregular smelting causing frequent chilling of hearth and blocking of tuyeres. The tests with the samples from the particular deposit was considered to indicate their unsuitability for production of pig iron in low shaft furnaces. The test data are given in Tables 11 and 12.

The jhama, when encountered during mining of coal, is at present, worked only to the extent that wining of coal dictates. There is no incentive to win this difficult-to-mine hard material as neither is there any established market nor is there any

TABLE 10 — CHEMICAL ANALYSIS OF SLAG AND METAL IN SUCCESSFUL 5 TON CUPOLA TESTS WITH JHAMA

(Jhama: Pig iron scrap = 1: 5)

Split charge	Metal C %	Si %	P %	Mn %	S %	Temperature of metal (°C)	Slag CaO %	SiO_2 %	MgO %	Al_2O_3 %	Fe_2O_3 %	Temperature of slag (°C)
With 100% hard coke	3·2	1·59	0·49	0·215	0·12	1280	29·03	40·92	2·96	19·95	8·55	1230
With 100% jhama	3·4	1·40	0·46	0·14	0·085	1350	29·02	43·62	4·56	18·88	2·72	1230

Size of pig iron scrap	152·7-12·7 mm 152·4-203·00 mm 50·8-76·00 mm
Size of jhama	101·6-152·40 mm
Limestone	38·1-50·80

Requisite amounts of ferro-silicon, fluorspar, ferro-manganese and soda ash blocks necessary for requisite castings were added.

Note — Tables 6-10 were reproduced from Report No. RR 176/64 of the National Metallurgical Laboratory, Jamshedpur.

TABLE 12 — ANALYSIS OF PIG IRON, SLAG AND TOP GAS USING 100 PER CENT JHAMA IN THE FUEL BURDEN

	Carbon %	SiO_2 %	FeO %	Al_2O_3 %	CaO %	MgO %	S %	CO %	CO_2 %
Pig iron	2·8-3·0	1·0-2·0	—	—	—	—	0·12-0·15	—	—
Slag	—	32·34	2	25	32-36	5	—	—	—
Top gas	—	—	—	—	—	—	—	24	4

Smelting extremely irregular causing frequent chilling of hearth, blocking of tuyers. Experiments indicate unsuitability of the use of the jhama for production of pig iron in low shaft furnace.

Tables 11 and 12 private communication.

TABLE 11 — TESTS WITH JHAMA (XV SEAM, DIGWADIH) IN LOW-SHAFT PILOT PLANT FOR PRODUCTION OF PIG IRON

Prox. analysis of jhama (Air dried)

Moisture %	Ash %	Volatile %	F.C. %
1·0	15·2	14·0	69·8

Composition of ash of the jhama

SiO_2 %	Al_2O_3 %	Fe %	CaO %	MgO %
52·8	34·2	4·1	3·4	4·7

price fixation. Variable quality of the jhama makes it doubtful if a sustained market can be found for it.

S. Gupta

References

1. Fox, C. S., *G.S.I. Memoir,* Vol. 56, 145-46.
2. Ghose, S. & Mukherji, Anoop K., " Studies on the effect of epithermal contact metamorphism of coal by lamprophyric sill ", *Qr. J. of Geo. Min. Met. Soc.*, Sept. 1968, 141.
3. Mookherji, S. K., Moitra, A. K. & Gupta, S., " Natural coke (jhama), its properties and possible utilization ", *J. Min. Met. & Fuel,* May 1967, 139.
4. *Annual Reports, Jharia Coal Survey Laboratory,* 1963-68.
5. *Annual Reports, Ranchi Coal Survey Laboratory,* 1957-62.
6. *Annual Report, Bilaspur Coal Survey Laboratory,* 1965.
7. *Annual Reports, Nagpur Coal Survey Laboratory,* 1964 and 1967.
8. Jatinder Mohan, Goswami, J., Chatterji, A. B. & Nijhawan, B. R., " Cupola operation with jhama coal as a substitute for foundry coke ", RR No. 176/64, NML, Jamshedpur.
9. Private communication on report of test with jhama in low shaft furnace.

Spotlight

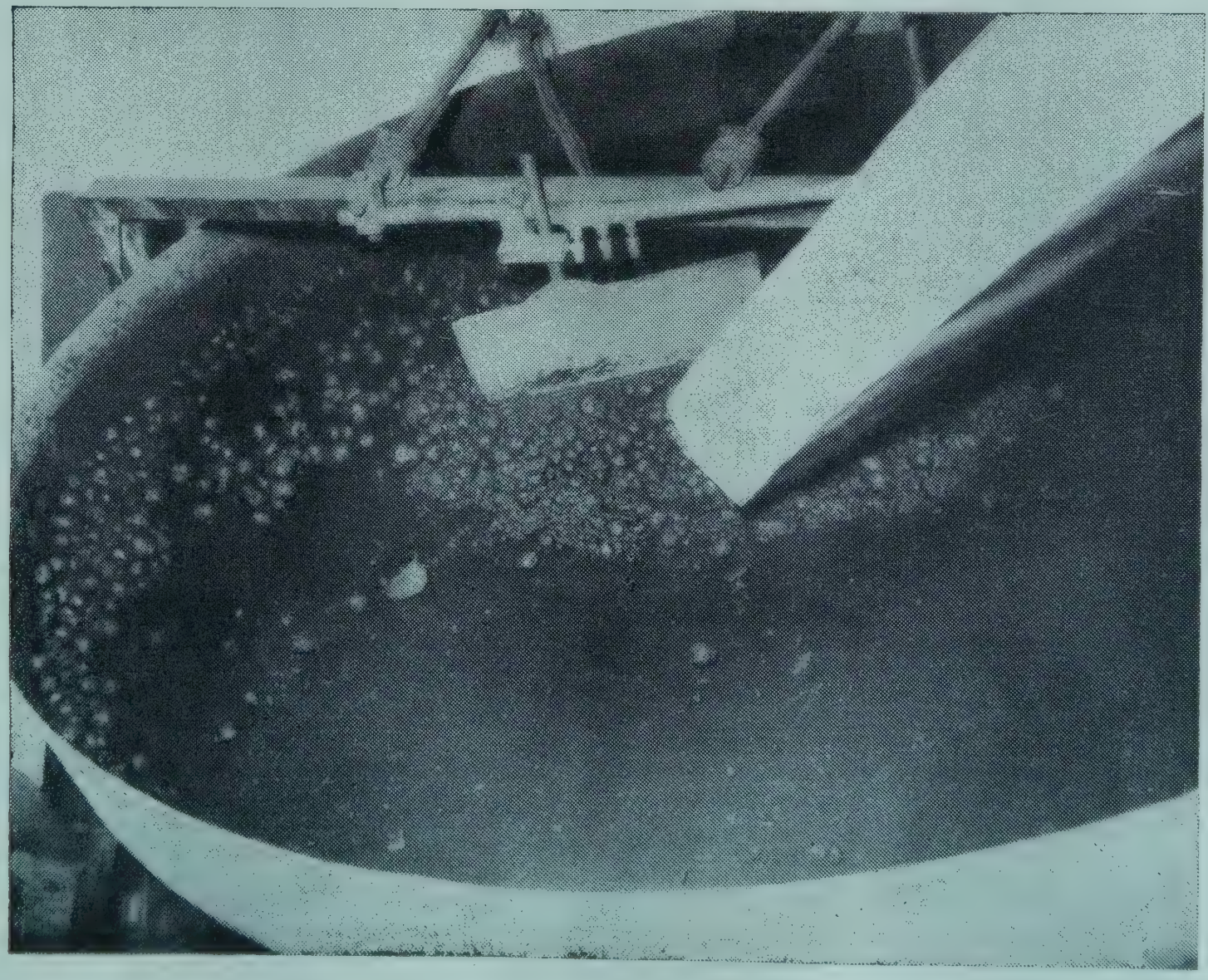
ON SCIENTIFIC ACTIVITIES

Smokeless Fuel by Spherical Agglomeration

Mining and processing of coal, be it for Iron & Steel industry, power production, domestic use, combustion purposes, or for any other consuming industry, leave behind a portion of it which does not find ready market. These are middlings, rejects and slurries from coal washeries; coke breeze or char from carbonization industry and slack coal from mining industry.

The process of briquetting has been developed to upgrade the size of fines and make moulded shapes out of them. The CFRI has now successfully developed a process (*Indian Patent No.* 127909) for production of sized, shaped, smokeless and strong agglomerates. The agglomerates which are suitable for domestic, industrial and metallurgical use are produced by the technique of pelletization followed by devolatilization.

The caking coals are crushed and, if necessary, suitably blended with other coals. The mixture is then fed to a pelletizer where strong pellets are produced. The green pellets are screened and sized pellets are dried in a continuous moving bed drier utilizing the waste heat contained in the flue gas from a devolatilizer which



PAN TYPE PELLETIZER (1 T/HR) WITH MIXER FOR PELLETIZATION OF WASHERY BYPRODUCTS AND LOW GRADE COALS

is subsequently used for coking of the pellets either in a moving bed or in heated sand carbonizer. Due to the high rate of heating at the stage of plastic deformation (400-500°C), the carbonizing period could be reduced to 20-35 min. depending on the size and moisture content of the raw pellets against 12-14 hr. in fixed bed carbonizer.

The main advantages of the process are: it is cheap; the equipment can be manufactured indigenously; the pellets are porous and homogeneous which facilitate burning in domestic ovens and are suitable for the production of ferr-manganese, ferro-silicon, ferro-chrome, ferro-vanadium, etc., by incorporating desirable ingredients.

An added advantage is that economic capacity of the plant can be as low as 100 t/day coal throughput.

The process is especially attractive for converting middlings which will be available in increasing quantities in future, into useful and attractive processed fuel for domestic use.

Silica Incorporated Briquettes as Improved Charge for Ferro-Silicon Manufacture*

Ferro-silicon of various grades are used for the reduction of alloying agents as well as an important intermediate to produce ferro-alloys. Better varieties of the material are mostly prepared in electric furnaces where reduction of silica in the presence of iron is effected with the help of carbon. For this, required amount of quartzite rock, charcoal and scrap iron ore are charged. Electrical energy is supplied to provide heat. The drawback of the process is that there is a considerable loss of power and high rate of electrode carbon consumption due to the low electrical resistivity of the charge. Many investigators tried to increase the electrical resistivity of the charge by mixing powdered silica with coking coal before carbonization to obtain coke. Though the coke obtained effected a saving in power, time and cost, the mechanical strength of the coke was found to decrease when the quartzite content exceeded 15 per cent.

Central Fuel Research Institute succeeded in developing a process for the manufacture of silica incorporated briquettes of suitable strength which are suitable for ferro-silicon and ferro-alloy manufacture. This process (*Indian Patent No.* 126552) is a modification of a technique earlier developed at the Institute for the production of 'formed coke' entirely from non-coking coal.

Non-coking coal or lignite was carbonized for obtaining char and tar. Coke breeze and HT tar required for the process were obtained from HTC plant. Char, coke breeze and quartzite were crushed to required sizes, mixed with a particular fraction of the mixture of tars and briquetted in a hydraulic press. The green briquettes thus obtained were subjected to heat hardening as in the case of formed coke process. Hardened cured briquettes were carbonized in an electric tube furnace whose temperature was raised to the required level. The carbonization temperature was maintained for two hours after which the briquettes were allowed to cool down.

An examination of the briquettes showed that the electrical resistivity went on increasing with more and more of quartzite, whereas the mechanical strength went on decreasing up to 40 per cent addition; after this no change was observed. Even the minimum mechanical strength (480 kg, i.e. 53 kg/sq. cm.) of the briquette was more than double that required in a ferro-silicon furnace.

Thermal treatment though lowered the electrical resistivity of the briquettes, even at as high a temperature as 1200°C, the resistivity was found to be nearly double that of metallurgical coke heated to the same temperature. On the other hand, mechanical strength was found to vary directly with temperature. Identical changes in the above properties may be expected during the passage of the briquettes to the ferro-silicon furnace.

The quality of the char was found to influence the mechanical strength of the briquettes. Using LT tar as binder, briquettes prepared from lignite char were found to possess the maximum strength. Talcher char briquettes also showed high resistivity towards crushing. Keeping lignite char-fine constant and varying the binder, briquettes with highest strength were obtained from LT tar. Next coming in the order was HT tar. Lignite tar yielded briquettes with lowest crushing strength which was less than half that obtained in the other two cases.

*Based on a paper Communicated to JSIR by R. S Ghosh, N. G. De, V. N. Sah & A. K. Moitra.

Special advantages of this improved composite briquettes are: (i) high electrical resistivity of the charge decreases power consumption, (ii) working voltage of the electric furnace can be raised, (iii) electrode consumption is reduced, (iv) increase in throughput and production, (v) better reduction of SiO_2 by intimately intermixed carbon and consequent decrease in raw material consumption, (vi) better control due to uniformity of size, and (vii) production time is reduced.

CFRI Suggests Measures for Improved Operation of Beehive Ovens

Consumption of hard coke in foundries is on the increase. The merchant cokeries are striving hard to meet the demand. However, due to operational problems, the production from the beehive ovens is much below their rated capacities and also the coke produced does not fully meet the specifications. On requests of beehive coke manufacturers, therefore, CFRI has conducted investigations recently for four parties. Two more projects are on hand. In each case, suitable remedies have been recommended. Adoption of the measures suggested by CFRI has greatly improved the working of the merchant cokeries in terms of economy, efficiency and quality of product.

Based on the study carried out for a battery of ovens in the Jharia coalfield, it was recommended that with the type of coal used for carbonization, the yield of coke could go up to 72 per cent from the present 55 per cent if efficient control of combustion conditions are maintained inside the ovens. The high overhead cost can be brought down by properly utilizing the labour which accounts for nearly 85 per cent of the overheads.

CFRI studies for a battery of beehive ovens in Assam have shown that the yield and quality of coke could be considerably improved by carbonizing the Namdung 60 ft seam coal at a faster rate under controlled conditions (the yield of coke was 43·5 per cent) and further improvement was achieved (yield 56·8 per cent) by blending 10 per cent finely crushed coke breeze. Satisfactory coke was obtained by carbonizing crushed Tirap slack coal having lesser market demand.

In case of another beehive ovens in the Raniganj coalfield, it was recommended that with Laikdih bottom seam coal which is currently being used, the carbonization should be carried out at a faster rate under controlled conditions of heating so as to produce good quality coke. The combustion conditions can be controlled by regulating air flow above the charge level and completely inhibiting it through the oven door. At the time of discharging, the oven door should be kept open for a minimum period to avoid unnecessary heat loss. If cokes of superior physical strength are aimed at, 25-30 per cent of low volatile coking Jharia coals should be blended and carbonized under conditions and rate as suggested above.

Another battery of ovens in the Jharia coalfield was yielding 61 per cent coke. The owners were interested in the possibility of improving the yield and quality of coke from a mixture of Kharkhar e XVIB seam coal with minimum proportion of Kirkend X seam coal which had to be transported from a fair distance. Existing working conditions in the beehive ovens were thoroughly investigated. Only 33 per cent of the coke yield was found to be of good quality. With controlled carbonization conditions, the yield of coke from XVIB seam coal alone increased to 70 per cent with about 44 per cent as quality I. With further modification in the preparation of the coal charge, the yield of quality I coke could be increased to about 70 per cent. It was found unnecessary to use Kirkend X seam coal, thus saving about Rs. 9000/- per month which was being incurred in transporting Kirkend coal.

It is noted during the above studies that the beehive ovens in general are very poorly maintained resulting in low yield of coke and deterioration in the quality of the product. Broadly, the following measures were suggested for the overall improvement and better quality of product: (1) proper maintenance of coke oven; (2) preventing of leakage of oven gas; (3) reduction in the charging time; (4) establishing optimum conditions for proper combustion; (5) use of good quality refractory bricks for the construction of oven walls; (6) uniform crushing of the charge; (7) adequate stock of raw material; (8) incorporation of optimum quantities of coke breeze to the charge; and (9) employment of adequately qualified and experienced personnel to man the ovens.

Potentialities of VIII Seam of Jharia Coalfield as Coking Coals*

Out of the eighteen seams of Jharia coalfield, the seams underlying IX/X seams have not atrracted much attention of consumers and producers due to the notion that these seams contain inferior quality coals (as measured by caking index, ash content, etc.), unsuitable for metallurgical use. Studies at CFRI and its Coal Survey Laboratory (Jharia) have shown that there are zones/sectors and definite depths in those zones where coking coal can be found. The VIII seam of Jharia coalfield, for example, contains good quality coking coal in the eastern zone. This observation assumes importance in view of the shortage of prime coking coals which may hamper future iron & steel production.

The seam has an approximate gross reserve of 383 million tons up to a depth of 610 metres according to the Committee on the *Assessment of Coal Resources of India* Vol. 1, 1963. A general tendency of the seam (thickness 1·5-2 m) to thicken towards the east (East Kirkend), is observed, but at the extreme south-east, it appears to have thinned (1·3 m) appreciably.

The ash in the coal gradually decreases from west to east with slight increase in the middle. The general variation is from 31 to 20 per cent. Volatile matter gradually decreases from west to the centre and then increases towards the east. In the eastern region the unit coal volatile is as high as 28·4 per cent against 20·3 per cent in the westernmost region. Caking index is more or less the same from west to the centre and then increases towards the east (14-22.) Phosphorus is low (0·02-0·05) except in an area in the middle.

Unit coal carbon in the seam remains almost constant (91 per cent) up to a certain distance beyond the central region towards east after which it shows a decreasing trend. Probably due to indifferent quality and bad cleaning characteristics of the coals from the western part, the coals are not considered coking. Amongst other properties, oxygen decreases from 2·15 per cent in the west to 1·04 per cent in the centre and then increases to nearly 4 per cent in the east.

Washability tests indicate that the yield of clean coal at 1·50 (ash 17-17·5 per cent) is 56-76 per cent in the east and only 18-35 per cent (ash 16-18 per cent) in the west. So far the caking index of the clean coal is concerned, it is found to improve appreciably on cleaning. From a projection of the above data for greater depths in the eastern region, it can be inferred that the quality may further improve.

*Based on *A Report on Assessment of Resources, VIII seam, Jharia coalfield*, prepared by Coal Survey Laboratory, Jharia.

Correction for Adsorbed Acid in the Carboxyl Group Estimation of Coal†

The base-exchange method of carboxyl group estimation employs pre-treatment of coal with hydrochloric acid so as to liberate the carboxyl groups. CFRI modified the original method whereby the time required for estimation was reduced to half an hour from fifteen hours. While carrying out estimation on coal macerals by the modified method it was observed at the Coal Survey Laboratory, Ranchi, that a considerable amount of chloride was tenaciously retained in the coal resulting in the formation of an equivalent excess of acetic acid by interaction with the base-exchange reagent and hence giving higher values for the carboxyl content. A correction was, therefore, called for in order to arrive at the correct figure.

An estimation of the acid and chloride contents of aqueous extract of acid treated coal confirmed that the chloride liberated during refluxing was entirely hydrochloric acid. The estimation of the chloride contents of the original acid-treated coals, their residues and filtrates after base-exchange reaction showed that only a part of the total adsorbed chloride was liberated and obtained in the filtrate. Hence, for correction, estimation of chloride content in the filtrate from each individual tests was necessary.

Figures for carboxyl group before and after applying the correction varied widely. Hence the correction factor is significant especially for the relatively higher rank coal.

†Based on a communication to *Fuel (London)*, by G. S. De, S. Tumuluri & K. C. Lahiri.

Notes & News

Committee and Meeting

A meeting of the Expert Committee with Shri G. B. Newalkar as Chairman, appointed by the Governing Body of CSIR to examine Dr E. E. Donath's (an US Expert on coal hydrogenation) report on CFRI proposal for Hydrogenation of Assam Coal to Oil, was held in New Delhi on 27 November 1970.

Besides Dr Donath's Report, the Committee also studied the two additional reports prepared by CFRI — one designed primarily to produce liquid fuels and the other producing chemicals with liquid fuels as byproducts and replacing natural gas with coal gasification for production of hydrogen.

The Committee noted the availability of considerable ancillary facilities at CFRI on coal preparation, coal-tar distillation, production and purification of hydrogen, production of catalysts as well as major facilities for hydrocracking, hydrofining and refining the crude that may be produced by hydrogenation. It noted what was now proposed was to provide a unit for primary liquefaction of coal for production of synthetic crude which could then be processed in the existing facilities. It noted that earlier estimates of CFRI (Rs. 15 lakhs) for the equipment was modified by Dr Donath to Rs. 20 lakhs. A considerable import content in the form of high pressure equipment will be involved for the project.

The Committee was also apprised of the recent trends in investment for the USA on coal conversion due to falling oil discoveries. Abundant coal resources and limited oil resources in India, in its opinion, puts this project as a priority national project.

The Committee felt the necessity of further R & D work for having necessary and concrete data both on the behaviour of different types of Indian coals and Assam coal in particular, as well as on quality and quantum of products that can be produced under different conditions before any major investment in commercial production could be suggested.

Being aware that financial provisions existed within the Fourth Plan tentative estimates, which have been recommended by the Working Group on Minerals and the BSIR, the Committee strongly urged that priority considerations be given to this R & D work, especially for production of chemicals and feed stocks from coal in addition to production of petroleum product substitutes.

■ The twenty-second Advisory Committee Meeting for Coal Survey Laboratory, Raniganj, was held at Sanctoria in the Conference Room of M/s Bengal Coal Co. Ltd., on 10 December 1970 with Mr Ll. D. Hughes, General Manager, M/s Bengal Coal Co. Ltd., in the Chair.

The Committee noted the incompatibility of the low caking index of the Badjna seam coal at Selected Jamburia colliery in relation to its medium volatile matter content. It was, however, realized that such abnormality was not peculiar to Badjna seam alone but was known to exist in other regions also and could be due to various factors, e.g. abnormal petrography, heat alterations or even oxidation. Further investigations were considered necessary.

Regarding the blendable property of Koithee seam coal in comparison to that of Argada, Sirka or Churcha coals, it was stated by CFRI that Koithee seam coal, in view of its rank, was expected to have better blending possibilities than Argada, Sirka and Churcha coals. The weak GK (LTC) coke obtained from Raghunathbatty coal was considered misleading because that might be due to oxidation. The higher coking property of Borachak seam was found to be consistent and confirmed.

Exploratory drilling in Poradiha proved the occurrence of all the Raniganj Measure coal horizons except R-VI. The seams have been found to deteriorate both in thickness and quality. Even the Dishergarh seam had become practically non-caking to weakly caking and the thickness of the seam in some of the bore holes was less than one metre. This was particularly noted towards the southern boundary fault.

Quality studies of Churulia and Kasta seams revealed that the latter in the western sector contained better coals in terms of caking property while other parameters were more or less similar.

The anomaly in HGI values of different washability fractions were explained in terms of distribution of petrographic fractions and shales. In general, higher the rank of the coal the lower was HGI but shales were also more easily grindable. A statistical correlation on this aspect has been published by CFRI. However, in odd cases exinites affected grindability of coals and in such cases the relationship between HGI values and power consumption may be vitiated considerably from the actual performance.

With regard to problems on behaviour of pulverizer and power stations equipment, the Committee was informed that the matter was being investigated by the CFRI on the basis of sponsored work by the DVC. Various factors, e.g. size of coal, mineral matter, moisture, equipment design and material of construction as well as combustion conditions were being evaluated. A systematic mineralogical survey of all power station coals was contemplated as a national task for combating erosion and corrosion problems and improving boiler availability.

National Seminar on Fuel Efficiency

The National Productivity Council, New Delhi, in collaboration with the CFRI, Coal Board and the Institute of Fuel (Indian branch) organized a Seminar on Fuel Efficiency during 5-7 December 1970 at New Delhi. Attended by over 300 delegates from various user departments and industries and inaugurated by Dr Atma Ram, Director-General, Council of Scientific & Industrial Research, the Seminar discussed in 5 sessions the following subjects: (1) Outlook for energy in seventies, (2) Energy substitution as an aid to productivity, (3) Energy policy in the context of our deve-

loping economy; (4) Fuel efficiency in (a) Transport sector, (b) Process industries and development of equipment, (c) Iron and steel industry, and (d) Power sector; (5) Education, research and training in promoting fuel efficiency; (6) Role of management in promoting energy efficiency. Besides these, there was a general discussion on back pressure turbines. Over 40 papers were presented and discussed. CFRI contributed 4 papers, namely: (1) Energy Outlook for India during 70s, by A. Lahiri and N. C. Sinha, (2) Some Typical Industrial Fuel Efficiency Tests, by M. M. Sen *et al.*, (3) Efficiency in Coal Utilization in India, Role of Education, Training and Management, by B. Acharjee and S. Ranga Raja Rao, and (4) Productivity and Power Utilization in Major Indian Manufacturing Industries, by N. C. Sinha, S. N. Ghosh and A. K. Moitra.

CFRI was represented in the Seminar by Mr M. M. Sen, S. N. Ghosh, Dr B. Acharjee and S. Ranga Raja Rao. Mr Rao was also a Member of the Organizing Committee on behalf of the Institute.

In the concluding Session of the Seminar, the following resolutions were adopted:

1. Wherever capital intensive industries are planned, the infrastructure facilities should be made part of the project and their establishment should be well synchronized with the main project with a view to making optimum use of the energy resources.

2. Whenever it becomes necessary in the national interest, particularly for more rational utilization of indigenous or imported energy resources, improvements of national productivity and saving of foreign exchange, financial incentives should be given to the users of energy for energy substitution.

3. The use of non-commercial fuel such as dung and firewood constitutes a substantial portion of the total energy consumption in the country. The changeover from non-commercial to commercial forms may be accelerated at the quickest possible pace. For the domestic sector, priority should be given to the establishment of well organized industries to produce substitute fuels and ensure its efficient nationwide distribution. A start may be made with urban areas and large townships spreading gradually to the country side.

4. Industries requiring large quantities of process steam should be liberally encouraged to integrate steam generation and electrical power generation by use of suitable equipment such as ' back pressure turbines '.

5. Concerted efforts should be made to intensify fuel economy drive throughout the country.

6. Keeping in mind the continuity of supply of energy at the minimum cost to the economy as the principal objective, use of different energy resources should be regulated through the operation of price mechanism and the quality of fuel should be considered as a factor. Particularly non-coking coal should be graded on calorific value correlated with a suitable price differential keeping in view the overall picture of reserves and size of the country in view.

7. In the national interest, the existing investments in organized fuel industry must be fully utilized before embarking upon new ventures, particularly those involving major foreign exchange.

8. For coordinated and integrated power development in the country, it is essential that the CEA already set up under the Electricity Supply Act of 1948 should be made to play its full role. Further, with a view to encompass the planning and development of all forms of energy, constitution of a statutory National Fuel and Energy Authority may be considered.

Conference on Research and Development in Industry

The Industrial Credit and Investment Corporation of India Ltd. held a Conference on Research and Development in Industry in Bombay on 15-16 December 1970. The Conference was attended by about 160 participants from industry, government, research laboratories, universities and finance institutions. Dr Atma Ram, DGSIR, inaugurated the Conference, Dr A. Lahiri, Director, CFRI, attended the Conference on invitation.

In his welcome address, Shri G. L. Mehta, Chairman, The Industrial Credit & Investment Corporation of India Ltd., called for a long-range strategy for promoting R & D in the country, and for this purpose suggested the formation of a high-level council of scientific policy which would include prominent scientists, planners and industrial leaders. Dr Atma Ram, inaugurating the Conference, cited the example of Japan which had achieved remarkable technological development and stressed that import of technology and indigenous development of technology are not alternatives or mutually exclusive. He referred to the ' credibility gap ' that seems to have developed between scientists and industrialists in India, and suggested that perhaps there was a need for a class of professional men and organizations capable of taking up the processes and products developed by research scientists and add their competence to design and engineer plant and projects with necessary guarantees for the industrialists to invest. Welcoming the springing up of such consulting engineering firms, he stated that lately some processes developed in the national laboratories have gone through this process of engineering through consultants and have resulted in successful industrial operations.

During the lively and vigorous discussions that took place in this two-day conference, the difficulties that come in the way of greater research effort in India were brought out and suggestions were made for improving research facilities, coordination of research effort, and the organization of R & D *vis-à-vis* its application in industry. Dr Lahiri emphasized the requirements of adequate goods and services, right kind of skill and the need for capital for the encouragement of research and development. He felt that industry should not depend exclusively on national research laboratories, as these laboratories had only a limited role to play. He felt that there was a lack of communication between laboratories and industries as neither side knew the needs of the other. He also stressed the importance of team work at different levels in research organizations. Regarding foreign collaboration he felt that the emphasis should be on importing of technical knowledge rather than importing of plant and equipment. Some of the most important suggestions put forward by the Conference are:

(i) The Committee on Science and Technology should consider organizing an expert group to identify problems of national importance such as air and water pollution, which require concentrated research effort.

(ii) The Council of Scientific & Industrial Research should consider establishing a central facility for dissemination of information on industrial R & D. It should also consider publishing an annual directory on new products and processes available in the country.

(iii) The national laboratories should consider publishing from time to time a list of sophisticated research equipment available with them and make these accessible to use by industry, research associations or research centres upon request.

(iv) The national laboratories should take measures to actively seek sponsored research from industries. Mutual cooperation between industry and laboratories will also be facilitated by periodic exchange of scientific personnel between the two.

(v) Industry should increasingly resort to national laboratories and Institutes of Technology for solving their technical R & D problems.

(vi) All industrial concerns should establish a R & D cell to keep abreast of technological developments in industry and to identify the company's R & D needs.

(vii) Each industry should consider establishing a cooperative research association to work on research problems of common interest to the industry.

(viii) Consultancy service should be made use of for effective utilization of R & D efforts.

(ix) Government should consider restoring the development rebate for R & D expenditure to the rate prevailing before 1 April 1970.

(x) Government should consider liberalizing its import policies for import of equipment and raw materials for R & D by raising the present free limit, and by instituting machinery for speedy disposal of licence applications. etc.

Research and Development Committee of CAC

A meeting of the Coal Advisory Council's Committee on Research & Development was held at New Delhi on 10 October 1969 with Dr A. Lahiri, Director, CFRI, in the Chair.

The new terms of reference of the Committee were as follows: (i) to examine the present state of research in coal and mining and to suggest measures for accelerating its progress; (ii) to suggest new schemes of research in coal and coal mining; (iii) to suggest measures for effective utilization of the results of the various research schemes; and (iv) to consider any other matter relating to research or development of the uses of coal which may be remitted to the Committee by the Coal Advisory Council or the Government or the Council of Scientific & Industrial Research.

While discussing the progress in the follow up action of the recommendations of the earlier meetings, the item on the increased use of blendable and substandard coking coals came up first. The Member-Secretary informed that a beginning in the right direction had already been made by the steel mills.

As regards adoption of selective crushing, the Chairman felt that it had not made any tangible headway. He informed the members that CFRI had developed such a low cost unit based on 'pneumatic separation'. The Chairman elaborated on the advantages and disadvantages of different processes, screens and crushers used in such units and recommended quick adoption of pneumatic separation units by HSL for their steel plants. Shri Anantharaman of HSL apprised the Committee that a project report on different systems of selective crushing, considering merits of different types of screens and crushers, had already been prepared.

In view of the resultant decrease in the consumption of coke in blast furnace contributing to conservation of meagre resources of coking coal, the Committee recommended for a Techno-economic Feasibility Study on the pelletization and pre-reduction of iron ores with high ash coke breeze. The progress in this direction had been reported to be limited to the laboratory scale. The Chairman opined that facilities for testing at least in semi-industrial scale should be created.

Production of metallurgical coke from non-coking coal was taken up next. The Chairman informed that CFRI and NCDC had jointly entrusted Chemical and Metallurgical Design Company with the task of preparing a feasibility report on the setting up of a 250-300 tonnes/day 'formed coke' plant in the outlying coalfield, based on CFRI process (to be ultimately integrated with a blast furnace of 250 tonnes/day capacity)*.

*The firm has submitted Reports to NCDC and CFRI on the feasibility of the CFRI process. It is now preparing a report for IDCOL for a formed coke plant to be integrated with a 250 t/d pig iron plant. CFRI is acting as coordinator in this assignment.

On the question of complete recovery of byproducts in the steel plants for the growth of pharmaceutical and fine chemicals industries, the Committee was informed that HSL had already set up an internal committee to go into the details of this aspect.

Prospects of underground gasification of coal was another important item discussed in the meeting. The Chairman suggested such techno-economic study for certain coal seams in India, particularly the lignite seams of Rajasthan. He said that by the process, it would be possible to generate cheap power in closed cycle gas turbine. In this respect he made a reference to the project report drawn up by M/s Humphreys & Glasgow Ltd. (at the instance of the Rajasthan Government).

Replying to the views of some members that such power generation might not be economical since with the availability of Chambal power, the scarcity had vanished, the Chairman reiterated that the power could be transmitted to Delhi and at cheaper price if the high cost of transportation of coal to the power stations at Delhi from Bengal-Bihar coalfields were taken into account. It was decided that Coal Board would initiate a formal discussion with the Directorate of Mining & Geology, Rajasthan, and then seek for Russian technical assistance.

Development of coal-based agro-industrial complex was suggested by the Chairman for deriving the fullest benefit which was not possible in case of isolated developments. He expressed that the beginning could be made with Singrauli and Talcher coals for the generation of electricity, production of fertilizers, pig iron, aluminium, etc. Appreciating the importance of the proposal, the Committee requested the Chairman to have concrete proposals prepared by CFRI and submitted to the Planning Commission.

Shri S. Bagchi of MAMC elaborated on the principles of hydraulic mining of coal and described the suitability of the process for mining coals of Sudamdih and Chasnala areas. After an elaborate discussion, the Committee recommended that such possibilities be examined in fuller details by a panel of exerts drawn from MAMC, Coal Board, DGMS, NCDC, CMRS and a report submitted to the Department of Mines & Metals for their consideration.

The potentiality of pipeline transportation under Indian conditions

was then discussed in the light of the fact that such procedure at certain throughput rates was proving quite economical and advantageous up to a distance, as compared to other modes of transportation. The Chairman referred to the already established practice and advantages of such transportation in the USA.

Shri Bagchi suggested transportation of coal from Raniganj to Bandel and or Durgapur to start with. The Committee felt that this would go a long way in relieving the burden on the railways. Shri Bagchi was requested to have a pilot scheme (feasibility report) drawn up by the MAMC in consultation with Coal Board and CFRI.

Shri Bagchi drew the attention of the Committee to frequent outbreak of fire in coal mines. In his opinion, the outbreak was in most cases due to auto-oxidation. As guidelines towards minimizing such hazards, he suggested (i) balanced ventilation on either side of coal pillars, (ii) the pillars might be made large enough to offer sufficient resistance, thus controlling flow of air to safe limit, or (iii) they might be made thin enough to increase the air flow sufficiently enabling quick dissipation of heat of oxidation. Smearing coal pillars with sodium silicate was found by CFRI to stop such oxidation. He apprised the Committee of the field trials undertaken with sodium silicate at Haripur colliery, Raniganj, and of successful results obtained. The Committee felt that some more field trials should be undertaken to establish the efficacy of the substance and as such a panel consisting of members from CMRS, Coal Board, DGMS, and Shri Bagchi himself should go into the details of the work and plan further action. Report of findings should also be communicated periodically to the concerned ministries.

Broaching on the subject of fluidized combustion of coal, the Chairman enumerated the advantages of this method for burning high ash coal with increased efficiency. In view of the high ash in Indian coals and the refractory nature of most coal ash not permitting use of cyclone firing, the process held high potential in our country.

The Chairman made a reference to the work being done at CFRI in this regard and viewed that the process could be fully developed at home if semi-commercial experiments could be conducted in collaboration with a power station. The Committee felt that pilot scale research should be undertaken immediately. As some engineering aid would be involved and an outlet for electricity generated in the pilot scheme was to be found out, power station at Durgapur or Chandrapura was considered as a suitable locale for the purpose. If Durgapur be the site, engineering assistance might be forthcoming from CMERI. The Committee felt that a concrete scheme be prepared by CFRI in collaboration with the Coal Board. Further, the Committee felt that the finance should come from Coal Board in the form of research grant.

Coal Supplies to the Proposed Steel Plants at Vizag and Hospet

The Ministry of Steel & Heavy Engineering envisages setting up of four blast furnaces of 2000 m^3 capacity each, two in each of the new steel plants at Vizag and Hospet where each of the blast furnaces will produce 1·2 million tonnes of hot metal. Thus the total hot metal production in view is 4·8 million tonnes.

A Sub-committee was formed by the Ministry to indicate the availability of coal from indigenous sources for basing the new steel plants.

The dry coal requirement as charged to the ovens, for a single plant of 2·4 million tonnes capacity, was estimated at about 2·78 million tonnes. But, for allocation purposes, the recommended figure is 3·12 million tonnes which is in full agreement with the present accepted norm of 1·3 tonnes per tonne of hot metal. The tentative blend composition in the view of the Ministry was prime: medium: blendable coals as 50: 40: 10.

The Sub-committee suggested providing facilities for blending and selective preparation to the extent technically feasible to those steel plants when a 45: 45: 10 blend may be found expedient. Such a shift, if found suitable, will result in the increased use of coals from nearby sources and consequently reduction in freight charge. The Sub-committee, therefore, suggested working out the coal requirements on the revised basis and keeping provision for supplying at the higher ratio of 50: 40: 10, if commercial tests demand so.

The Sub-committee felt that coal supplies for prime coking coal (2·80 million tonnes) can be met from Talgoria area of Jharia coalfield, medium coking coal (2·80 million tonnes) from Washed Ramgarh; Raw Mohuda Bottom seam (Murilidih/Bhatdee); Raw Barakar from Raniganj coalfield (Begunia-Laikdih) and blendable coal (0·64 million tonnes) from Churcha-Katkona area. Some amount of Disergarh coal can be used as blendable coal if its use in the blend for coke making is considered advantageous in spite of higher freight charges.

The mineable reserves of prime coking coal from Talgoria area, according to a Polish Feasibility Report, is 375·4 million tonnes up to XII seam from the top. The seams above XII contain good quality coals with VM above 22 per cent (unit coal) and the XII seam less than 22 per cent on the same basis. The average ash content varies from 15-24 per cent.

Talgoria has been recommended for development in two stages. At the envisaged production level, 4·2 million tonnes of coal per annum will be the output from this area. Nearly 50 per cent or 2 million tonnes of this production may be used raw and the remaining 2 million will have to be washed yielding at least about 1·0 million tonnes of required grade of prime coking coal. Thus production of Talgoria should more than adequately meet the total prime coking coal requirement of both the plants.

Studies by CFRI (on the Feasibility of an Industrial Complex at Ramgarh) and the Pierce Management Corporation (USA) have independently indicated that out of the 12 seams, only four seams (VIII, VII Top, VII Bottom and VI) have been proved in the Ramgarh coalfield. The reserves of recoverable coal through washery from these seams have been estimated at 38·74 million tonnes, seam VI accounting for over 20 per cent of the total. As seam VI contains high ash (nearly 32 per cent) coal, the Sub-committee suggested exclusion of the seam for the present. As a result, the availability of washed medium coking coal will be 1·10 million tonnes/annum in place of 1·35 million tonnes/annum as assessed by the Pierce Management Corporation, USA. The Sub-committee also suggested that the possibility of washing Ramgarh coals in Gidi washery may be explored in which case the construction of a new washery can be avoided.

The remaining 1·70 million tonnes, as indicated earlier, will be met from Mohuda area and Barakar Measure of Raniganj coalfield. Karo seam of Bokaro and expansion of

Swang may also be considered to meet the requirement of Vizag and Hospet.

Churcha colliery, one of the sources of blendable coals for the proposed steel plants, is already under development by NCDC. The proved reserve is 35 million tonnes. In addition, an indicated reserve of 10·4 million tonnes is also noted. The present production of 0·3 million tonnes/annum is half the target production of 0·6 million tonnes/annum.

Out of the three main workable seams (I, III and V) in the Katkona colliery, seams I and III are of grade I quality while the other is of inferior quality. Out of an indicated reserve of 43·16 million tonnes in seams I and III, the proved reserve is 15·4 million tonnes. The mine is planned for a total production of 0·5 million tonnes/annum. This mine may be developed to supply the requirements of the new steel plants as a part of the Churcha coal is being used in the Bhilai Steel Plant. Yet another source of blendable coal may be the Argada-Sirka seams in Karanpura coalfield.

As for the transportation of coal to the Vizag steel plant no difficulty is envisaged so far as prime coking coal supplies are concerned. The movement may be either by rail or rail-cum-sea route. The transportation of medium coking coal by rail from Ramgarh itself presents no difficulty. The problem arises when it is required to be sent to Gidi for washing and then the washed coal to Vizag. Raw Mohuda or Barakar Measure of Raniganj present no such difficulties in transportation. Although transportation of blendable coal from Churcha/Katkona has problem, these coals should be adopted unless technological considerations dictate otherwise.

The railway route via Tatanagar, Wardah, Kazipet, Wadi and Guntakal to Hospet for the supply of prime coking coal to Hospet steel plant being circuitous, two alternative routes have been suggested. One route follows the east coast line and then proceeds via Guntur-Guntakal to Hospet. Other route is to transport the coal to Kharagpur via Adra and thence to Haldia wherefrom to Madras or Goa by sea and then by rail again. The rail route will be via Guntur-Guntakal if Madras is taken as the port. In case of rail haulage, the Guntur-Guntakal section will have to be converted into broad gauge. In case of rail-cum-sea movement, the railways favour Madras as the port on the consideration that conversion of Guntur-Guntakal section to broad gauge would be economical for the present. Such a conversion will again facilitate the movement of blendable coal from Churcha/Katkona area.

As a measure of reduction in freight charges, the Sub-committee also considered partial supplementation of indigenous sources by imported coal. It has also suggested examination of the suitability of the Kanhan Valley coals of Chhindwara, MP, as an alternative indigenous source. The coals of the western part of this coalfield are medium to strongly caking in nature. The reserves are estimated at 100 million tonnes out of which the extractable part is 50 million tonnes.

The Sub-committee noted the work of CFRI on carbonization tests with foreign coals as well as with Kanhan valley coals. The tests with foreign coals were not encouraging as not more than 15 per cent of non-coking coals could be utilized in the blend for making metallurgical coke. Tests with Kanhan valley coals showed that both individually and in mixture, the coals yield satisfactory coke provided they are selectively crushed 100 per cent through 3 mm. Dry or stamped charging has further beneficial effect in this regard. Incorporation of at least 15 per cent Jharia coals in blends has been found advantageous for controlling the ash in coke.

The Committee expressed the view that tests should be done on blends of Kanhan valley coals and Australian coals. If favourable results are obtained, rapid prospecting of the block should be given priority. The committee felt that if Kanhan valley coals could be used in place of Bengal-Bihar coals, it will save the lead distance by about 400 km apart from helping development of the central parts of the country.

The Committee also attached great importance to the project on the production of formed coke from non-coking coals of Singareni, Talcher, Ghordewa, etc. Whole or partial replacement of coke by formed coke will improve the economy of the projects. In this regard, the Committee referred to the project report on the production of formed coke and pig iron at Talcher by M/s Chemicals & Metallurgical Design Co. (P) Ltd. at the instance of Government of India and the Government of Orissa. CFRI is collaborating in the preparation of the report.

The Committee noted the views of Dr A. Lahiri, Director, CFRI, who recommended that the Vizag plant should be based on coke to be supplied from a newly built coke ovens unit in the Bokaro coalfield. The new steel plants should also utilize local coals, e.g. Singareni or Talcher slacks for pre-reduction to reduce coke consumption by 20-30 per cent depending on economic metallization, use available fuels to reduce further consumption and gas demands be met by producer/gas integral plants based on local non-coking coals besides the available refinery gases and tar produced therefrom.

For the Hospet, CFRI suggested that it should be based on pre-reduction of pellets using char or coal from Andhra or lignite char. The pre-reduced material may either be exported as such or smelted in electric furnaces. Alternatively, pre-reduced pellets could be smelted with formed coke for which technology will have to be developed.

The Director, CFRI, strongly felt that under Indian conditions, steel plants based on imported coals will not only be highly uneconomic but technically unsound and will lead to great operational problems in practice.

Unesco Seminar on Problems of Transition from Laboratory Research to Industrial Application

A Seminar with the above title was organized by Unesco and the Government of India at NCL, during 9-14 December 1970. Dr A. Lahiri, Director, CFRI, was one of the delegates on behalf of the Government of India. Some 30 invited scientists from 14 Asian countries participated in the Seminar, which was inaugurated by Dr Atma Ram, DGSIR. 21 papers submitted on invitation by these participants formed background materials for exhaustive discussion in 3 sessions, namely (i) prerequisites to successful industrial research, (ii) rationale of technology development and the transition of laboratory research to industry, and (iii) transition of laboratory/pilot plant research/development to industry.

In his inaugural address, DGSIR said that development should be a major responsibility of the industry and not mainly of the research laboratory. The laboratory's role should be that of the 'idea producer'.

Dr Lahiri presented an elaborate "Note on Reorganization of R & D in India" and advocated that the model presented could form the

basis for establishing R & D facilities in developing countries.

Among the major recommendations of the conference are the following: in view of the imbalances in the availability of trained laboratory researchers, engineers, technicians, technologists, technocrats/managers in most of the participating countries, it was recommended that the overall training of manpower should be coupled with the plans of social and economic growth by a planned process of education. This could be done by the respective governments by adequate funding in the desired directions. The importance of management training for scientists of all senior cadres in R & D institutions was stressed.

For improving the efficacy of R & D institutions in developing countries in the proper identification of projects, it was recognized that collection and dissemination of local and international market information is of great necessity. This can be arranged by establishing market information exchange centres in different countries. Since there are no such centres in South Asia, international assistance may be secured for providing expertize in market research methodology and in establishing such agencies.

Observing that a high order of impact on the economic growth of the developing countries can be effected by adapting, assimilating and improving upon imported technologies, the seminar recommended the following measures: (1) Large industries in the developing countries should be encouraged to establish integrated R & D and engineering and design facilities which will facilitate the expansion of these units on the basis of their own 'inhouse' research. Government may subsidize such inhouse research by affording adequate incentives. (2) Until such R & D base is established, the large industries in these countries should take advantage of the national laboratories. (3) The government should also promote industries in key sectors by funding research on important problems in research establishments in public and private sector industries and in other R & D institutions. In this connection it was felt that it would be mutually advantageous to establish bilateral collaborations in R & D activities between different South Asian countries.

It was important to be selective in R & D inputs in view of the limited resources and hence it was necessary to have a well-defined national scientific and technological policy to promote indigenous research in selected fields of highest relevance. The government should also have a policy of implementation of such plans by making available necessary funds.

For successful horizontal transfer of technology from laboratory research to industry, the seminar recognized the need for providing financial guarantees of the performance by R & D institutions. Encouragement of sponsored research was emphasized as it is most likely to lead to the success of transfer of technology. Scientists and technologists were exhorted to strive to bridge the communication gap existing between them and the business entrepreneurs.

The seminar also discussed the factors which promote vertical transfer of technology within an organization. These included clear definition of objectives; acceptance of the objectives by the top management, and acceptance and communication of the objectives throughout the research, development, production and marketing organizations; and encouragement of R & D scientists to work in production units, marketing or other departments in the organization. For achieving success in large and difficult projects, a total systems approach was found essential. This would involve the constitution of a team from various disciplines and expertize in the technology transfer chain.

Trends in Fuel Research

In a meeting of the Institution of Fuel Commonwealth Liaison Group held in Ottawa, Canada, on 31 May 1970, under the Chairmanship of Dr H. E. Crossley, members from the participating countries briefly dealt with the trends in fuel research in their respective countries. India was represented in that meeting by Dr A. Lahiri, Director, CFRI, and Shri S. B. Sarkar, Chief Combustion Engineer, Coal Board, Calcutta. The highlights of the points discussed are given below.

United Kingdom

According to Dr Crossley the major trends in fuel research in UK were the conversion of appliances and industrial plants to make use of natural gas and the very great efforts being made by the National Coal Board to develop fluidized bed combustion. C. A. Roast, representing an industrial organization, stated that his company was interested in the use of fluidized bed combustion to reduce air pollution. Dr N. M. Potter referred to decreasing supplies of coking coals, and the consequent work being done on blending. He also stated that there is the increased interest in solvent extraction of coal.

On the mining side, mention was made of the work of the UK Safety in Mines Establishment besides the two million pounds a year budget of the Coal Board on research and development of coal mining practices and machinery. The research activity of the Gas Council was very largely on developing a computer based optimum control of the complicated system of natural gas high pressure pipelines to get the best return on the enormous capital put into it.

Canada

Dr N. Berkowitz said that in Canada a great deal of effort is being devoted to exploration, exploration geology, and transportation and safe storage of metallurgical coals. They had a broad interest in non-fuel application and pollution abatement programme. In the area of natural gas, much work had been undertaken in basic chemical analysis. In the field of petroleum the interest in Western Canada related to the production of oils from sources like oil sands and characterization and possible uses for heavy oils. Some coal companies were doing extensive studies to avoid ecological damage. Dr D. S. Montgomery mentioned hydrogenation of heavy oils, formed coke for metallurgy, and a programme of aerodynamics in flame research to reduce pollution as their major interest.

Mr Ignatieff stated that his department was emphasizing research on air and water pollution, e.g. the handling of oil slicks, pollution not only from combustion sources but from conversion processes of sulphide ores. Because of competition from the United States where good market exists for nuclear fuels, more emphasis was being made to cheapen the cost of extraction of uranium and thorium. He drew attention to the North Slope Alaskan developments in oil.

Australia

Dr Durie said that in Australia considerable effort was being made to solve problems associated with combustion of coal for power generation, including fouling problems with brown coal in South Australia. In the field of bituminous-coal the problem on the precipitation of fly ash was attracting interest

in Australia. There was much activity in the area of industrial carbons.

Presently, Australia's export climate was so healthy and the industry was not particularly interested in research except that it would like to see developments concerning mining and preparation. There was much interest in aerial exploration for coal. There are plans for a research organization for oil and gas, and also a nuclear power station.

New Zealand

Mr W. Milne said that their interests were on better utilization of New Zealand coal.

India

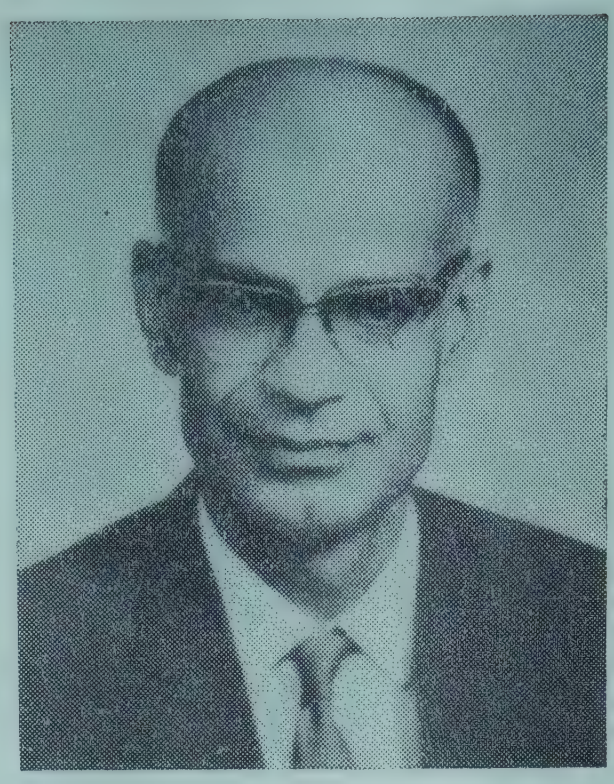
Dr Lahiri pointed out that the two main problems in India were concerning utilization of high ash coals (40-50 per cent) and shortage of coal for metallurgical coke. Technique such as fluid bed combustion of coals for steam generation and formed coke process for converting non-coking coals into hard agglomerates were, therefore, of special interest to India. Other matters receiving attention were related to preparation, cleaning and dewatering of fines; formed coke production, etc. India has plan for hydrorefining and hydrocracking of residual oils. There was not much natural gas and the proved reserves of oil was low. Hence, there is interest in coal conversion techniques, especially of the unique coals of Assam to oil products. He also gave an account of the programme of development of nuclear power in India where utilization of thorium in fast breeder reactors was the major problem.

Dr A. N. Ghosh, DG, ISI, Retires, Shri S. K. Sen Succeeds

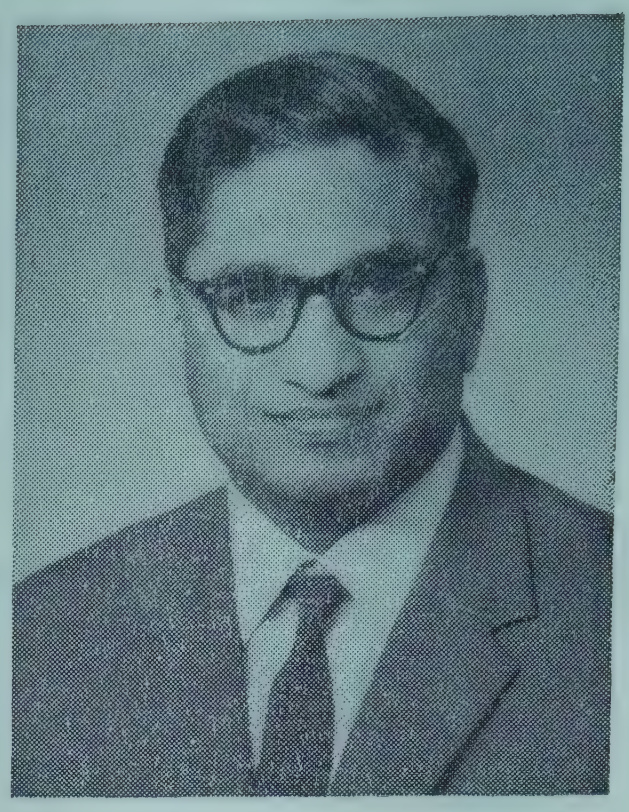
On 9 January 1971, Dr A. N. Ghosh laid down his office and Shri S. K. Sen took over from him as Director General, Indian Standards Institution.

Dr Ghosh is an eminent chemist, metallurgist and a distinguished standards engineer. Dr Ghosh and his worthy predecessor, Dr Lal C. Verman have been responsible for all-round recognition and increasing support the ISI is receiving from within the country and outside. Both in their turn have directed the programmes and activities of ISI and together they have pioneered the growth of ISI and through it the standardization in India.

Dr Ghosh took charge of the Government Test House, Calcutta



Dr A. N. Ghosh



Shri S. K. Sen

(which is now known as National Test House), in 1953 after having served in Rangoon for the preceding five years. His interest in the standardization work grew and he became deeply associated with it since joining the ISI as Joint Director in September 1956. Key to the success of the ISI, according to Dr Ghosh, is ' cooperation '. From a meagre staff of 4 in 1947, ISI now employs 1200 people and enjoys cooperation from 25000 members.

Dr Ghosh was associated with the Central Fuel Research Institute as a Member of its Executive Council and other Committees.

We extend to Dr Ghosh good wishes for a long, happy and fruitful retired life.

The Director and members of staff of CFRI offer their felicitations to Shri S. K. Sen on his appointment as Director General, ISI. Shri Sen has been intimately connected with the ISI having joined it in 1949. Educated in Calcutta (M.Sc. Applied Physics), Shri Sen received training in industrial standardization in USA in 1953-54 and acted as Consultant (1965-66) to British Standards Institution in UK on changeover to metric system. Earlier, he was entrusted with the task of planning and programming the changeover of Indian Standards to metric system, consequent on the enactment of the Standards of Weights and Measures Act, 1956. Shri Sen went to Iran as Adviser on Weights and Measures and Certification Marking to ISIRI. He has also assisted UNDP ISO, Industrial Standardization in Copenhagen (Denmark), etc. Shri Sen was awarded the K. L. Moudgill Prize (of ISI) for the year 1970.

High Grade Steels made more Cheaply

Cheaper, harder and more corrosion resistant steels which retain their strength at high temperatures may be available as a result of a new technique of steel strengthening being developed by a team of scientists in the Department of Metallurgy at the University of Newcastle. The technique known as ' constant activity ageing ' consists of introducing nitrogen atoms into the metal from an ammonia-hydrogen gas mixture at a carefully controlled concentration and at a constant temperature. This is in contrast to conventional methods of steel hardening which require the introduction of carbon atoms into the metal at high temperatures, a rapid cooling to room temperature and then further heating at some intermediate temperature.

Strengthening normally occurs by the formation of particles of carbides and nitrides — often too small to be visible in an ordinary microscope but just discernible at magnifications of at least 100,000 in an electron-microscope. The strength and hardness increase as the size of the particles decreases and as their number increases. When all the carbon and nitrogen atoms dissolved in the steel have been used by the formation of these carbide and nitride precipitates—called ' zones ' when they are just visible under the electronmicroscope — no further hardening can take place.

With the new technique, on the other hand, the introduction of nitrogen into the steel is continuous and as these atoms are used up to form zones they are automatically

replaced from the special gas mixture whose composition, temperature and flow rate are all important. No depletion of the nitrogen occurs in the steel and zone formation and the consequent hardening and strengthening of the metal continue until the gas flow is stopped. This has the further advantage of ensuring that the required degree of hardness can be obtained by controlling the gas.

To produce the heat and corrosion resisting properties of special high quality steels such as stainless steel and steels used for tools and dies in the manufacturing industries, large quantities of expensive metals such as chromium, nickel, molybdenum, tungsten and vanadium must normally be added. In the present process, the nitrides are more effectively dispersed throughout the steel than has hitherto been possible. This means that steel treated by the technique will acquire a high strength and a high heat and corrosion resistance. Moreover, the properties of existing high quality steels can be obtained with smaller quantities of expensive alloying metals mentioned than usual. This opens up the possibility of a significant reduction in the price. [*Science Journal*, August 1970, 19.]

Hydrodesulphurization (HDS) Process

As a result of research effort of 30 years and costing some 15 million dollars, Gulf oil has developed a process for reducing the sulphur content of petroleum fuels, a major source of atmospheric pollution. The process employing hydrogen-reduction is better than the processes using adsorption, thermal processing and chemical treatment techniques. The process uses a reactor containing a catalyst (6 per cent carbon by wt) with high activity and long life. The catalyst is remarkable in that it is claimed, even the presence of up to 65 per cent by weight of contaminants (nickel, vanadium, sulphur, etc.) does not significantly affect its activity.

The mixture of feed and hydrogen-rich gases is fed into a reactor after being heated in the furnaces. The two sets of equipment preceding the fractionation units can be operated either independently or together according to the process needs. When reactor effluents are separated in a high pressure separator, the gaseous effluents are recycled through a scrubber and the liquid stream is run into the fractionator; desulphurized fuel collects at the bottom of this fractionator. The process also provides for the removal of the fine particulate matter from the bottom fractions of crudes before the feed enters the reactor. This measure considerably reduces the pressure drops. Pilot and commercial studies on various feed materials and process variables show the process to be capable of reducing the sulphur content of the feed stock from as much as 4·2 per cent to as little as 1 per cent by wt. In controlling the sulphur content in the product, the most important variable is the catalyst temperature, this depending on the character of the feed material. The process costs have been worked out to be 55-60 cents per barrel of the charge material. [*British chem. Engng*, May 1970, 599.]

A New Cryogenic Hydrocarbon Extraction Plant

For the recovery of liquid hydrocarbons from natural gas, a new cryogenic plant with commercial potential is available from Kellog Company, USA. Because of its better efficiencies and higher quality products, the process is expected to replace current methods of production. A plant, replacing an obsolete plant built in 1940 with a feed capacity of 150 cu. ft./day of wet natural gas, has recently gone on stream in Hastings, West Virginia.

In the plant, natural gas feedstock first enters a drum where lubricating oil, free water and any dirty solids are removed. Then these gases pass through drier, filter and a feed cooling section before coming to separator where about half of the recoverable hydrocarbons are removed. Uncondensed vapours are then treated to yield 87 per cent of the ethane, nearly 99 per cent propane and practically all the butane and gasoline in a separator at 135°F. Methane is separated in a demethanizer and the bottoms liquid is fractionated in a series of four towers to obtain ethane, propane, isobutane, normal butane and natural gasoline products. The gasoline product before its final storage is subjected to a copper sweetening process to convert mercaptan sulphur to the less objectionable disulphide.

The compressors for the ethylene-propane refrigeration system are operated from a common shaft coupled to a 20,000 h.p. gas-turbine. This is the first commercial process to incorporate the gaseous isobutane purification method. The plant is designed to operate at 75 per cent of normal ethane product requirements. [*Brt. chem. Engng*, March 1970, 303.]

Bihar Governor Shri Barooah visits CFRI

Hon'ble Shri D. K. Barooah, Governor of Bihar, visited the Central Fuel Research Institute on Sunday, 21 February 1971. The Governor had detailed discussion with the Director of the Institute, Dr Lahiri. Evincing a keen and wide range of interest in the Institute's projects such as conversion of coal to oil and chemicals — the Assam coal being perhaps the world's ideal choice for such conversion — smokeless domestic fuel for the urban and rural areas, etc., the Governor spent over three hours inspecting the various pilot plants and laboratories of this premier fuel research establishment. He was also apprised of the integrated scheme of resources development in Ramgarh/Karanpura area of Bihar which the Institute has drawn up. The potentialities for coal-based industrial complexes attracted his special interest.

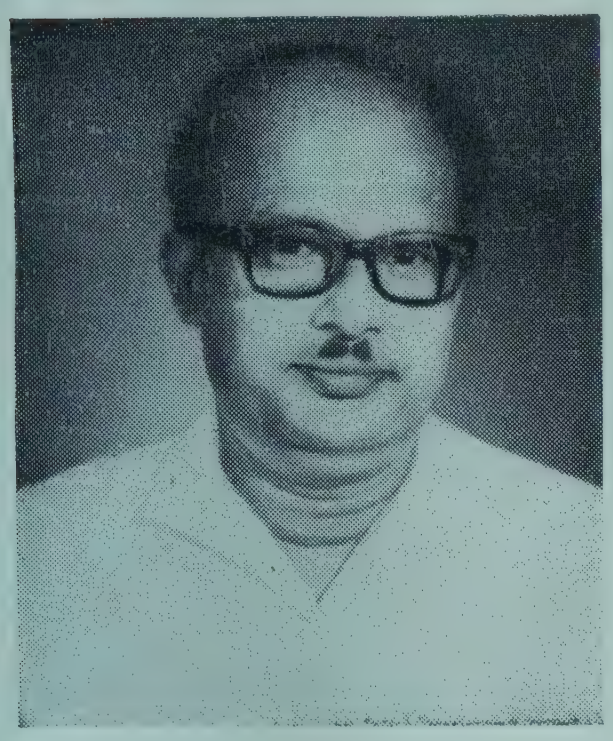
Honours and Awards

(i) Shri G. G. Sarkar, Scientist, CFRI, is one of the six recipients of the National Minerals Award for 1969-70. The honour bestowed on him is in recognition of his distinguished contribution in coal preparation for more than two decades.

Shri Sarkar joined CSIR services as a Scientific Assistant in the research scheme on washability of Indian coals in 1947 which became a part of CFRI activity in 1948. Shri Sarkar has been responsible for many laboratory and pilot plant developments on coal beneficiation. He along with his colleagues in Coal Washing Division of CFRI has assisted in the planning of about a dozen of coal washery projects in India both in the public and private sectors and has conducted guarantee and performance tests on a number of washeries under operation in this country. His division is functioning as a training centre for coal preparation technologists. Besides having compiled over 30 technical reports, he is also the author of more than 125 research and review papers, published in both Indian and foreign journals. He has a number of patents too. He has written a booklet on Coal in Bengali, entitled ' Koyla ', which has been published by Visvabharati Granthalaya in their popular series.

Amongst the important and internationally recognized contributions made by Shri Sarkar and his team

SHRI G. G. SARKAR RECEIVING THE MINERAL AWARD FROM DR TRIGUNA SEN



SHRI B. K. MAZUMDAR

SHRI N. N. CHATTERJEE

on coal preparation science and technology, mention may be made of the evolving of an index for comparing and correlating the washability characteristics of different coals, a suitable coefficient for representing the integrated efficiency of washing baths, a graphical method to determine optimum specific gravities for mixed coal washing, a new washability diagram for representing the petrological constituents of a coal, a novel technique for simultaneous upgrading and dewatering of small coal, a standard washing circuit for coking coal beneficiation, as well as development of an improved system of coal flotation by use of grids and of a float and sink apparatus for testing of fine coal and ores, now being fabricated and adopted in West Germany.

Shri Sarkar has been the Convener of the Panel on Coal Washeries set up by the Indian Standards Institution since 1963. He is now serving as Member-Secretary of the Technical Committee on Coal Washeries constituted by the Government of India to review the performance of various coal washeries in India. He is also concurrently associated with several other Technical Committees.

As a TCM participant, Shri Sarkar spent six months in the USA in 1956 and studied the design and operation of coal washing plants. Subsequently in 1960 he visited foreign countries as a member of Indian delegation and studied developments in mineral beneficiation. In 1962, he presented two papers at the Fourth International Coal Preparation Congress at Harrogate, UK.

(ii) A Paper entitled "Mechanism of Coal Pyrolysis in Relation to Industrial Practice" by Shri B. K. Mazumdar and N. N. Chatterjee, has been selected by the Coke Oven Managers' Association (Indian Section) for award of Silver Medal for the year 1970. One of the authors (Shri B. K. Mazumdar) presented the paper in a technical session of the Association held at Burnpur on 26 August 1970.

(iii) Dr A. Lahiri, Director, has been nominated Vice-Chairman of both Chemical Division Council and Standing Working Committee for Petroleum and Coal and Their Products Committees of Indian Standards Institution, New Delhi.

Deputation

Shri Tarapada Ganguly, SSA, Instruments Division, was deputed to Central Electronic Engineering Research Institute, Pilani (Rajasthan), for a three-month training (w.e.f. 19-10-1970) in Electronic Instrumentation.

Resignation

Our best wishes to Shri A. C. Bhattacharjee, JSA, who has relinquished his post at CFRI [w.e.f. 2-3-1971 (AN)].

CFRI ABSTRACTS

REGIONAL CLASSIFICATION OF JHARIA COALS BASED ON THEIR WASHABILITY CHARACTERISTICS, B. Banerjee, G. G. Sarkar & A. Lahiri [*J. Min. Met. F.*, XVIII (1970), **9**, 322].

On the basis of available data on the washability characteristics of Barakar Measure seams of Jharia coalfield, an attempt has been made in this paper to study the range of variation in the cleaning possibilities of the coal seams, both in vertical sequence and in lateral extents. From the results of this study, it has been found possible to draw some broad lines of demarcation whereby the entire coalfield is divided into three regions or zones (western, central and eastern) in which the recoveries of clean coal, both on fixed ash and fixed gravity basis are more or less well defined. So also in vertical succession, following the stratigraphic sequence, the coal seams, from the point of view of their cleaning characteristics, can be divided under two major groups. The first group, comprising XIII-XVIII seams, shows much better cleaning characteristics than the second group in which seams V-XII are included. The proposed classification closely follows the probable conditions of sedimentation of these seams as established from geological evidences.

CROP RESPONSE WITH HUMIC ACIDS FROM COAL, N. B. Paul & Gulab Singh [*Symposium on Chemicals & Oil from Coal*, 6-8 December 1969, Dhanbad (India)].

The paper deals with pot experiments conducted under green house conditions on maize crop showing the effect of humic acids from two different sources, namely from lignite and farmyard manure.

The results show that humic acids added at 0·01 and 0·05 per cent to the soil give significantly higher yield of maize crop, uptake of nitrogen by crop and its nitrogen content over control.

Reasons for stimulating effect of humic acids on crop growth and uptake of nitrogen are discussed.

FORMATION OF HCN BY THE PYROLYSIS OF NITROGEN-ENRICHED COAL, L. V. Ramachandran, T. Saran, P. N. Mukherjee & A. Lahiri [*Symposium on Chemicals and Oil from Coal*, 6-8 December 1969, Dhanbad (India)].

The feasibility of producing HCN by the pyrolysis of nitrogen-enriched coal has been investigated. Slow as well as shock pyrolysis of nitrogen-enriched coal was carried out at high temperatures. While the yield of HCN remained constant on slow pyrolysis at all the temperatures, it increased with the temperature of pyrolysis on shock heating and a maximum yield of 266 lb HCN/ton was obtained at 1200°C. But a high percentage of the fixed nitrogen appeared as elemental nitrogen in all cases. The mechanism of HCN formation is discussed from considerations of the yields of different products such as methane, ammonia, hydrogen, carbon monoxide and nitrogen on pyrolysis.

PORE STRUCTURE OF LOW TEMPERATURE CHARS, T. N. Roy & S. P. Nandi [*Fuel, London*, 1970, **49**, 346].

Sorption of CH_3OH and η-C_4H_9OH at $P/P = 0{\cdot}5$ was determined on low temperature (500-700°C), chars produced from five samples of coal (carbon 80-84%). The chars show higher sorption for molecules of smaller size. A char from 83 per cent C coal heat treated at 600°C shows sorption capacity for CH_3OH and C_2H_5OH in the ratio of 10: 1. An activation energy of 9·6 kcal/mole was obtained for the diffusion of nitrogen (temperature 25-50°C) into the pore-system of the char. Activation by air at low temperature (200-40°C) reduces the selective adsorption capacity of the char. Estimation of the micropore space of the activated chars were obtained from CO_2 adsorption data by the application of Dubinin equation.

Chief Editor: S. RANGA RAJA RAO

Editor: SAMIR SEN *Assistant Editor*: R. S. SAHA

Yearly Subscription: Rs. 4 This Copy Re. 1

Available from

CENTRAL FUEL RESEARCH INSTITUTE, P.O. F.R.I., DT. DHANBAD, BIHAR, INDIA

PHONE: JHARIA 6205. GRAMS: RESEARCH, JEALGORA

PRINTED AT THE CATHOLIC PRESS, RANCHI

Registered with the Registrar of Newspapers for India Under No.

R.N. 2872/57

Vol. 21
No. 3

FRI NEWS

SEPTEMBER
1971

5 SEP 1971

IN THIS ISSUE

EDITORIAL
(Hard Coke Industry in India) 37

HARD COKE MANUFACTURE IN INDIA ---------- 38
T. C. Tarafdar,
K. Raja &
A. K. Moitra

COALS OF PATHAKHERA AREA, PENCH-KANHAN-TAWA VALLEY COAL-FIELD — AN APPRAISAL -- 46
C. Chatterjee,
E. Duraimani,
R. N. Kudwalli &
K. Y. Shrikhande

TRENDS IN THE DEVELOPMENT OF LUBRICATING OILS ---------- 52
Endre Vamos

SPOTLIGHT ON SCIENTIFIC ACTIVITIES

ORTHO-PHTHALONITRILE FROM ORTHOXYLENE -------- 58
PINE OIL AS A FROTHER FOR COAL FLOTATION ------ 59
MECHANISM OF COAL PYROLYSIS AND INDUSTRIAL PRACTICE - 59
A CONCEPTUAL STRUCTURE FOR ASSAM COAL ---- ---- 60

NOTES & NEWS

CFRI SCIENTIFIC COMMITTEE MEETING ---------- 62
INDIAN INSTITUTE OF MINERAL ENGINEERS — ANNUAL MEETING ---------- 62
COAL ADVISORY COUNCIL MEETING --------- ---- 63
ANNUAL GENERAL MEETING OF THE INDIAN MINING ASSOCIATION ---------- 64
ANNUAL GENERAL MEETING OF THE INDIAN COLLIERY OWNERS' ASSOCIATION --- 64
SYMPOSIA/SEMINAR ------- 64
COAL RESEARCH PROGRAMME OF THE U.S. BUREAU OF MINES 64
POLLUTED WATER TREATMENT WITH FLY ASH ------- 66
LEAD-FREE PETROLEUM FUEL FOR AUTOMOBILES -------- 66

STAFF MATTER ------ 67

VISITORS ---------- 69

CFRI ABSTRACTS ------ 70

Hard Coke Industry in India

COKING industry in the world is perhaps more than two centuries old. In India, coke making had its beginning about a century ago. After the national independence, iron and steel production got a boost. The Hindusthan Steel Ltd. and the Bokaro Steel Ltd. came into being along with the expansion of the established steel plants in the private sector. Foundry industry also grew alongside with the greater availability of pig iron. This led to the rapid growth of the coking industry. From a production of about 2 million tonnes of coke in 1950, it has grown today to over 11·5 million tonnes of coke manufacture annually, with prospects of continued expansion in demand corresponding to increase in iron and steel manufacture capacity. The growth of the coking industry is traced in some detail in an article in this issue of the *FRI News*.

Being aware, since inception, of the limitations of reserves of good coking coals, the CFRI devoted efforts, its own and in collaboration with the Coal Blending and Coking Research Committee, to study the coking potentialities of the various Indian coals and establish blends of coals for use by the various cokeries with emphasis on increased use of non-standard coking coals, to make coke of acceptable grade for the metallurgical industries. This study led to the development of techniques enabling replacement of 50 per cent or more of the scarce prime coking coals of the country. For all the public sector coke ovens, the CFRI provided the blend composition, techniques of preparations, data on scurces of supply, design information, etc. As a result of the Institute's efforts, it is now recommended as a standard practice to use up to 50 per cent prime coking coal and the rest being blendable coals for coke making. CFRI studies have also led to adoption of other innovations in coking practice, such as selective preparation of charge and to the understanding of mechanism of coking, etc. An important development arising out of these researches is the CFRI Formed Coke process of making coke from entirely non-coking coals. Commercialization of the process, which is awaited, holds much promise for the growth of carbonization industry. Offshoots of this development is the production of fluxed ash formed coke, silico coke and other additive impregnated cokes to suit the specific needs of individual industrial application. (*Continued on page* 72)

HARD COKE MANUFACTURE IN INDIA

Introduction

THE evolution of the modern coking industry has an interesting background. The development in thought, technology and design, right from the passing reference[1] made by the Greeks in 317 B.C. to the present-day sophisticated, giant, silica byproduct ovens, has been fascinating. In England and Germany, attempts were made in the sixteenth century to carbonize coal. Coking in 'piles' gradually changed to coking in 'mounds' and the coke yield obtained progressively increased from 33 to 55 per cent. The early type of ovens[2] were of the Meiler type and, later, the beehive coke ovens came up. Around 1763, the beehive coke ovens were commissioned in England and in 1841 in the United States. The very first crude byproduct coke plant is reported to have been built in Germany in 1766.

Soon after, considerable developmental work took place progressively to improve the byproduct plant. As regards the heating aspect, horizontal heating flues changed over to vertical heating flues and the Francois oven[1], the first oven built with such heating flues in Germany, could be mentioned as the forerunner of modern byproduct oven. Coppee, who have many firsts to their credit, improved upon this oven (1861) by reducing the width to the modern level (from 36 to 18 in.), introduced dampering system for air admission to flues and started use of crushed coal for carbonization. Siemens introduced the system of reversible regenerators in 1864 and in 1896 Otto-Hilgenstock incorporated 'burners through openings beneath the vertical flues'. Further developments were made by Simon-Carves, Koppers, Willputtee, Carl-Still and others and the modern compound regenerative under jet and gas gun type of ovens have resulted. The structure of the conventional coke oven process has remained essentially unchanged during the last six decades or so though rotary hearth coking[3] has also been attempted recently.

In India, coal mining started towards the last quarter of eighteenth century and the history of coke making dates back to the nineteenth century. It is reported that Kulti Works of the Indian Iron & Steel Co., established in 1875, started initially with charcoal before changing over to coke. The Bhadravathi Iron & Steel Works in Mysore also used charcoal as its early blast furnace fuel. Coking started in the primitive type of ovens and when the Tata Iron & Steel Co. was founded in 1908, their requirement of coke was met from Coppee Coke Ovens of the byproduct non-recovery type. Today, the old beehive coke ovens and the modern coke plants coexist to meet the requirement of about 9 million tonnes of hard coke for the growing iron and steel industry and other users.

Beehive Coking Industry

Beehive coking practice was introduced in India in the nineteenth century. The industry made a modest start and through these years it has expanded with the number of ovens increasing steadily. By 1950 the production of beehive coke was of the order of 0·15 m.t. per year out of a total of 2·4 m.t. of hard coke. The coke manufactured from the byproduct plants was nearly double this amount (0·31 m.t.); the remaining being the production from steel and chemical plants, which is normally used by them at their end. During the last two decades, the production of coke from the beehive ovens has registered a steady increase which is to the extent of about 266 per cent. Though the number of ovens built at the various collieries at different periods is not exactly known, the number of ovens existing at present has been catalogued and a list of them indicating their capacity is shown in Appendix I. While in 1964-65, the number of ovens[4] installed at various collieries were 2140 out of which about 1740 ovens were working at that time, presently the installed ovens number about 3100 with only about 130 ovens remaining out of commission. To meet the demand of hard coke many new batteries are likely to be built shortly. The growth of beehive coke production is depicted graphically in Fig. 1. But for the

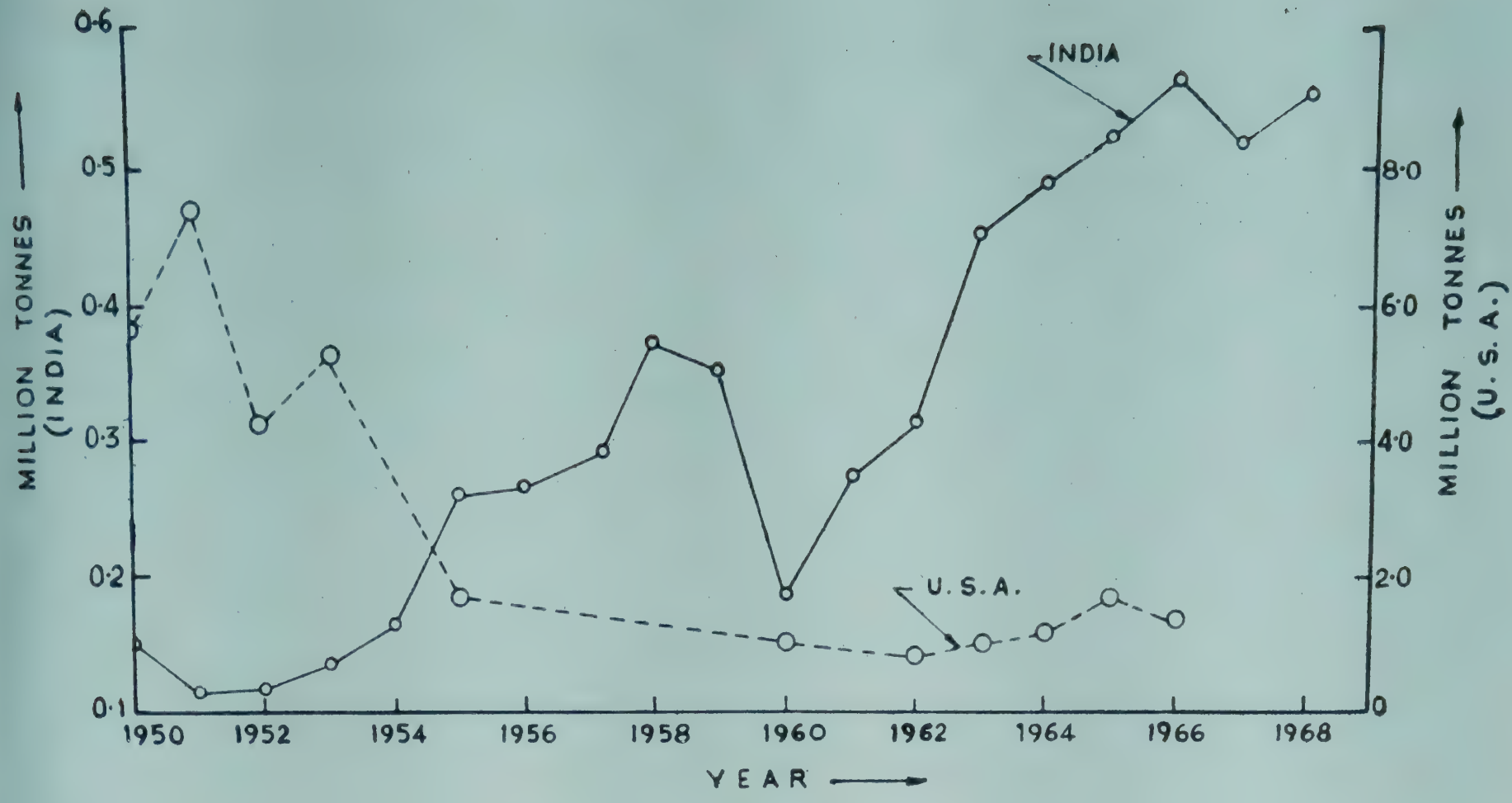


FIG. 1 — PRODUCTION OF BEEHIVE COKE IN INDIA AND USA

period 1959-63, there has been a continuous rising trend.

In this context, it is interesting to compare the pattern of production[5] of beehive coke in the United States. It is reported that between 1850 and 1910 the number of beehive ovens increased phenomenally and during the period 1880-93, all coke made was from beehive ovens. But, the byproduct coking industry which was started in 1892 recorded steady progress and, after 1910, the beehive coking started declining. The trend in the production from 1950 to 1966 is also shown in Fig. 1 for a comparative study of the Indian situation.

The history[3] of coke making in Canada also is more or less similar to that of the USA. Although beehive coke ovens are now reported to be extinct in Western Canada, this early form of coke making was in practice in Alberta and British Columbia from the last century till recently. In 1910 about 0·41 m.t. of beehive coke was produced and it was only after 1918 that the production of byproduct coke surpassed the beehive coke production.

In India, on the other hand, though the number of byproduct ovens has increased (as will be seen later), beehive ovens have not gone out of date. The beehive ovens in India use mostly lower grade coking coals. During 1963-64, the breakup[4] of the consumption of different grades of coals was as follows:

Gr. II, IIIA, IIIB	16·0%
Gr. C, D, E	19·5%
Gr. F, D	13·5%
Gr. H, HH	51·0%

The coal consumption tc coke production ratio is naturally higher than that of byproduct coking and is about 1·5 or 1·6:1. However, recent investigations[5(a),5(b)] carried out by CFRI in a few beehive ovens in the country have revealed that the productivity could be considerably increased, provided proper operational measures are taken in the running of the batteries.

Nevertheless, it will not be out of place to point out that beehive coke has increased in production and consumption only because byproduct coke is not available to meet the entire demand of the consuming industries.

Byproduct Coking Industry

The Indian byproduct coking industry started in 1908 when 50 Simon-Carves regenerative ovens were built for the East Indian Railway at Giridih. The plant had an installed carbonizing capacity of 152,400 t/year. Though this oldest plant has outlived its useful life, the present production

capacity of coke is estimated to be around 50,000 t/year. The plant produces premium grade, low ash, low phosphorus coke for industries.

A battery of 40 ovens were built by M/s Koppers Inc. in 1914 for the Burrakar Coal Co. Ltd. at Loyabad. The plant has a carbonizing capacity of 120,000 t/year.

In 1918 the Bararee Coke Plant came into existence with 35 Simon-Carves waste heat ovens having an installed capacity of 91,000 t/year. There was a programme of increasing the number of ovens to 40 but this did not materialize.

The Lodna coke plant was commissioned in 1920 and consisted of 60 Simon-Carves waste heat ovens with a carbonizing capacity of 132,000 t/year.

Between 1922 and the Second World War, Simon-Carves built 6 batteries with a total of 230 ovens for the Indian Iron & Steel Co., Burnpur. The same contractors also built 30 waste heat ovens for the Kulti Works of the Indian Iron & Steel Co. The capacity of the plant was 91,000 t/year.

M/s Semet Solvay built their first Indian plant of 25 ovens at Bhowrah in 1934. The ovens had horizontal flue heating arrangement and were of the waste heat type having a carbonizing capacity of 50,000 t/year. Though the plant is very old now, it is still in operation and produces hard coke.

It was in 1934 that Simon-Carves received their first contract from the Tata Iron & Steel Co. Ltd., Jamshedpur, for building a new coke oven battery and byproduct plant[6]. It consisted of 54 compound underjet ovens. With this addition, the position in India in 1935 was that out of 790 ovens, 437 (or over 55 per cent) were of Simon-Carves, 180 Coppee, 150 Willputte, 90 Koppers and 25 Semet Solvay ovens. By 1937, two more batteries of 55 ovens each were added at TISCO by the same firm and the three batteries together had an annual carbonizing capacity of 130,900 tonnes.

The fifties saw the completion of the seventh battery at IISCO, Burnpur. At TISCO the building of fourth battery of 52 compound ovens having a carbonizing capacity of 445,000 tonnes per annum was also completed. Further, in 1952, 102 Simon-Carves regenerative ovens were added to the Kulti Works of IISCO (capacity 300,000 t/year).

'Still' ovens were first set up by Indian coking industry when in 1953 sixty regenerative ovens with a carbonizing capacity of 325,000 t/year were built by M/s Carl-Still for the Fertilizer Corporation of India (Sindri Unit). This plant has the feature of additional facilities for stamp-charging, the first and the only one of its kind in India.

From 1956 onwards, considerable progress in the Indian coking industry is noted. This is due to emphasis on industrialization in the Plan periods. In order to achieve the targets of iron and steel industry, the coking industry also had to keep pace with the development and, therefore, the coke ovens attached to the private sector steel works were expanded and new batteries were started in the public sector steel plants at Rourkela, Bhilai and Durgapur of M/s Hindustan Steel Ltd. (founded in 1954).

In TISCO, complete reconstruction of the first three batteries, the earliest of which was twenty years old by that time, commenced in 1954. The first battery was rebuilt with the original 54 ovens and was commissioned in 1956. The second battery was rebuilt with 67 ovens in place of the original and was started in 1958. Battery 3 was rebuilt with 57 ovens and was also put into commission in 1958. All these ovens were of Simon-Carves compound underjet type having a nominal capacity of 18 tonnes per charge. In addition, 26 Dieder type ovens each of 20 tonnes capacity, were also lighted up in October 1957.

At IISCO, the eighth battery was commissioned in 1958 and the ninth battery was almost at the final stages of completion, both being engineered by Simon-Carves.

Under HSL, it was in Rourkela that the first battery of ovens went in production in December 1958. This consisted of 70 Otto ovens in two blocks of 35 each. The second battery with the same number of ovens was put into operation in 1960 while the third of similar type and number of ovens was ready for operation in 1962. With the commissioning of the fourth battery in February 1967, the capacity of coke oven plant increased from 1·26 to 1·88 m.t. of coke per annum. All these ovens have an average width of 400 mm.

The first Russian type PVR ovens were commissioned in Bhilai in January 1959. The battery, consisting of 65 ovens, had an annual carbonizing capacity of 560,000 tonnes. The second and third batteries, also of the same number and capacity, were put to work in December 1959 and December 1960 respectively. The fourth

battery was started in October 1964 while the fifth was commissioned in December 1965. The sixth battery was started in November 1966. All the batteries have the same number and type of ovens as mentioned earlier.

At Durgapur, under the aegis of the Durgapur Projects Ltd., another coal based industrial complex was begun Coke, gas and chemicals are the main products from this complex. The first battery of 29 ovens of the Still regenerative type was commissioned in 1959 and the second in 1960. These two have an annual carbonizing capacity of 487,680 tonnes of coal. A third battery of the same type was put to work in 1967. The fourth battery which is also of the same capacity is ready and is expected to be commissioned soon when the coke production will be of the order of 0·64 m.t. annually.

Later, at Durgapur, where the steel plant was built by a British Consortium, the construction of the coke ovens was done by M/s Simon-Carves. The first battery of 78 ovens was commissioned in 1959. Each oven had a carbonizing capacity of 18 t/day. The second and third batteries were commissioned in 1960 and 1961 respectively. The total carbonizing capacity is about 5300 tonnes coal/day or 4000 tonnes of coke/day. With the expansion of the works to 1·6 m.t. of steel, the coke ovens were also expanded and the fourth battery was started in 1966.

It will be observed that the growth of Indian coking industry has been quite significant. The rate of increase in coke production can be assessed from Fig. 2, in which (i) byproduct coke (from merchant ovens), and (ii) coke from steel and chemical plants have been shown separately. Since the production in the Sindri Chemical Plant has been more or less the same and no expansion has taken place, the rising trend in graph (ii) can be attributed to the increased production in the steel works. But as pointed out earlier, the coke made in the steel and chemical plants is not normally available for other consumers. While the availability of byproduct coke has just been doubled over that during 1950, the coke from steel and chemical works has registered a four-fold increase in 1966. An up-to-date list of the various plants operating in the country is given in Appendix II.

It may be worth to compare[7,7(a)] the byproduct coke produced in various countries of the world. Available data covering the period 1913-68 are presented in Table 1. It is found that though the Indian production is the lowest, the increasing trend is noticeable.

Pilot Coking Plants

A review of the Indian coking industry will be incomplete without the mention of the part played by the extensive and continuous research being carried out in the field of carbonization. The entire preliminary work of establishing suitable blends for carbonization in the public sector steel

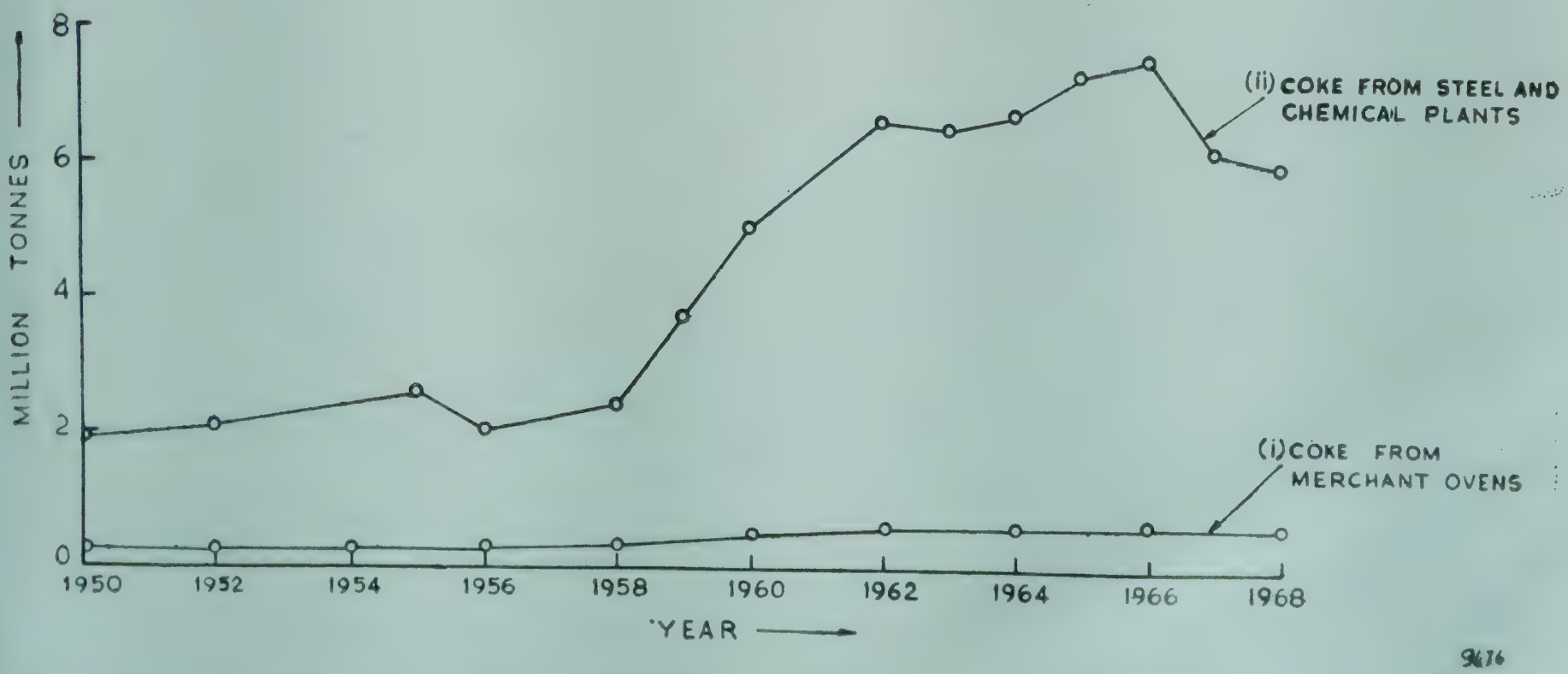


FIG. 2 — PRODUCTION OF COKE (OTHER THAN BEEHIVE) IN INDIA

TABLE 1 — BYPRODUCT COKE PRODUCTION IN VARIOUS COUNTRIES (m. tonnes)

Country	Year					
	1913	1940	1950	1960	1966	1968
USA	42·0	51·8	66·0	55·3	61·1	58·0
USSR	4·4	21·1	27·7	56·2	68·5	69·9†
UK	12·8	15·6	15·7	19·1	16·3	16·5
W. Germany	31·7*	43·8*	27·3	39·7	39·9	36·3
India	N.A.	N.A.	2·2	5·5	7·5	7·8

*Germany as a whole. †Figure for 1967. N.A., data not available.

and chemical plants was carried out in the semi and pilot plants of the Central Fuel Research Institute and the Coal Blending & Coking Research Sub-committee, Jamshedpur. The unique features[8-11] of the High Temperature Carbonization Pilot Plant installed at CFRI and the other pilot and semi-pilot plants available for research and testing purposes in our country have been described elsewhere. These plants are still regularly used to study the coking potentialities of coals and blends from newer sources.

Many experiments on various technical aspects, viz. selective crushing of coals[12], blending of coals[13], stamp-charging of coals[14,15], measurement of shrinkage of coke on carbonization[16], effect of rate of heating[17], etc., have been carried out in the CFRI plant.

Standardization of Hard Coke

With many cokeries manufacturing coke for use at their end or elsewhere, the need for assessing the quality of coke was felt and this naturally led to the standardization of the quality of hard coke. The Indian Standards Institution (ISI) has already formulated standards for hard coke and foundry coke. Standards for gas cokes and coke for ferro-alloy industries are tentatively finalized. Standards for blast furnace coke are further being revised. These standards take into account the particular need of the users of coke for blast furnaces, foundries, producer gas and water gas generation and ferro-alloy industries. The existing standards (both final and tentative) for all the above types of cokes are given in Appendices III-VII.

Acknowledgement

The authors are grateful to Shri S. N. Jha, Coal Superintendent Office, Dhanbad, for supplying information on the beehives in our country. Thanks are also due to the Director, CFRI, for his permission to publish this paper.

T. C. Tarafdar, K. Raja & A. K. Moitra

References

1. *Koppers Becker Coke Ovens*, Copyright 1944, Koppers Co.
2. Keerl, A. G., *Transactions of the M.G.M.I.*, **XXIX** (3) (1934), 243-70.
3. Botham, J. C., *Symp. on Coal Science & Tech.*, Mines Branch, Ottawa (Canada), March 1967, 37.
4. *Report of the sub-committee of the production and preparation committee on hard coke*, April 1965.
5. Finney, C. S. *et al.*, *Symp. on Coal Science & Tech.*, Mines Branch, Ottawa (Canada), March 1967, 30.

5(a). *Report of investigation on the production of coke from Bhulan Bararee Beehive Ovens*, June 1969.

5(b). *Interim report on improvement in performance of Kharkharee Beehive Oven*, September 1970.

6. Green, E. W., *Iron & Steel Review, T.M.P. Number* 1960.
7. Anon, *Coke & Chemistry*, **11** (1964), 3.

7(a). *Statistics for Iron & Steel Industry in India* (Hindustan Steel Ltd., Ranchi), 1970.

8. *First Report of the CBCR Sub-committee*, Fuel Research Committee Report No. 2 (CSIR), 1948.
9. *Second Report of the CBCR Sub-committee*, Fuel Research Committee Report No. 3 (CSIR), 1952.
10. Das Gupta, N. N., Shrikhande, K. Y. & Rao, V. V., *COMA Year Book (U.K.)*, 1960, 438-46.
11. Das Gupta, N. N., Banerjee, S., Chatterjee, N. N. & Menon, M. V. P., *Indian Construction News*, (July 1960), 213-16.
12. Das Gupta, N. N., Rao, V. V. & Lahiri, A., *J. Mines. Metals Fuel* (Special) **7** (1959), 53-59.
13. Das Gupta, N. N. & Lahiri, A., *J. Mines Metals Fuel*, **7** (1959) 66-70, 78.
14. Das Gupta, N. N., Singh, K., Raja, K., Chatterjee, N. N., Sen Gupta, D. & Lahiri, A., *Indian J. Technol.*, **1** (6) (1963), 233-39.
15. Singh, K., Raja, K., Chatterjee, N. N., Menon, M. V. P., Banerjee, N. G. & Moitra, A. K., *Gas World*, **CLXV** (1967), 4302, 155-158; 4306-254-57.
16. Singh, K., Raja, K., Das, P. K., Menon, M. V. P., Chatterjee, N. N. & Das Gupta, N. N., *Metals & Minerals Review*, Dec. 1964, 11-19.
17. Das, P. K., Chatterjee, N. N., Menon, M. V. P., Singh, K., Raja, K., Das Gupta, N. N. & Lahiri, A., *Indian J. Technol.*, **3** (12) (1965), 396-99.

APPENDIX I — LIST OF BEEHIVE OVENS

Sl No.	Location	No. of ovens	Production of coke per oven per day (tonnes)
1	East Bhuggatdih	118	0·75
2	Khas Bhuggatdih	17	0·91
3	Bhalgora	100	0·83
4	Burragarh	30	0·91
5	Dhansar (NBH)	40	0·75
6	Kustore (Alkusa South)	54	0·83
7	Kustore (Kustore Sec.)	70	0·83
8	Kusunda Nayadee	30	0·77
9	Pure Kustore	136	0·91
10	Goluckdih	72	0·91
11	South Goluckdih	42	0·91
12	South Kujama	122	1·00
13	Central Kujama	24	1·00
14	North Kujama	30	1·00
15	New Marine	100	0·85
16	W. Gopalichuck	40	0·71
17	Kendwadih	30	0·89
18	Bhowrah	102	0·73
19	Central Bhowrah	33	0·92
20	Khas Jayarampur	270	1·00
21	Khas Jeenagora	30	1·00
22	Jeenagora East Bararee	24	0·83
23	South Tisra	24	0·83
24	West Godhur	150	0·84
25	Godhur	246	0·87
26	Bhulan Bararee	50	0·70
27	East Katras	30	0·83
28	Katras Choitodih	140	0·83
29	Ramkanali	16 (4 country ovens)	0·83
30	Lakurka	60	0·83
31	Mudidih	60	0·83
32	Angarpatra	18	0·83
33	North Tetulmari	44	0·83
34	New Teturia	20	0·47
35	Bilbera	60	0·55
36	New Govindpur	8	0·17 (country oven)
37	Tundoor Khas	4	—
38	Kharkharee	56	0·91
39	Ashakuti/Phularitand	90	1·00
40	Mahespur	90	0·93
41	Shampur	36	0·83
42	Sri Gopinathpur	24	—
43	West Ramkanali	30	0·91
44	Bokaro Jharia	20	0·92
45	North Damoda	92	0·92
46	Madhuband	60	0·92
47	Kessurgarh	134	0·92
48	Pipradih	24	— (country oven)
49	Sitanalla	—	—
50	Namdung	18	— (country oven)

Note — The above list refers to the situation of early 1970.

APPENDIX II — LIST OF BYPRODUCT COKING PLANTS

Sl No.	Location	No. and type of ovens	Carbonizing capacity (t/annum)
1	TISCO	230 (Simon-Carves (SC) Under Jet (U.J.); 26 (Dieder Reg.)	2,540,000
2	IISCO	80 (SC, U.J.) 228 (SC twin flues)	2,275,840
3	Bararee	35 (SC WH)	91,000
4	Lodna	60 (SC WH)	132,000
5	Bhowrah	25 (SS WH)	50,800
6	Loyabad	40 (Koppers', Reg.)	120,000
7	Sindri (FCI)	60 (Still Reg.)	325,000
8	Durgapur (W.B. Project)	116 (Still Reg.)	975,300
9	Durgapur (HSL)	312 (SC Reg.)	2,533,000
10	Rourkela (HSL)	290 (Otto Reg.)	2,133,000
11	Bhilai (HSL)	390 (PVR Russ)	3,600,000
12	Giridih (NCDC)	50 (SC Reg.)	152,400

APPENDIX III — INDIAN STANDARDS SPECIFICATIONS FOR HARD COKE — IS : 439-1965

Sl No.	Characteristics	Requirement		
		Gr. I	Gr. II	Gr. III
1	*Proximate analysis* (on dry basis)			
	(a) Ash %, max.	20	24	28
	(b) V.M. %, max.	2	2	2
2	Sulphur % (on dry basis), max.	0·70	0·70	0·70
3	Phosphorus % (on dry basis), max.	0·30	0·30	0·30
4	*Shatter Index*			
	(a) Over 38 mm (%), min.	85	85	—
	(b) Over 13 mm (%), min.	97	97	—
5	*Micum Index*			
	(a) Over 40 mm (%), min.	75	75	—
	(b) Through 10 mm (%), max.	14	14	—
6	*Haven Stability Factor*			
	On 25 mm (%), min.	40	40	—
7	Porosity, %	35-48	35-48	—

APPENDIX IV — DRAFT INDIAN STANDARD SPECIFICATION FOR BLAST FURNACE COKE — IS: (TENTATIVE)

Sl No.	Characteristics	Requirement	
		Gr. I	Gr. II
1	Moisture, % (by wt.), max.	4	4
2	V.M. % (by wt.) (on dry basis), max.	1·5	1·5
3	Ash, % (by wt.) (on dry basis), max.	25	25
4	F.C., %, (by wt.) (on dry basis), min.	73·5	73·5
5	Total sulphur, % (by wt) (on dry basis), max.	0·70	0·70
6	Phosphorus, % (by wt.) (on dry basis), max.	0·25	0·25
7	*Micum Index*		
	(a) Total on 40 mm, % (by wt.), min.	76	78
	(b) Through 10 mm, % (by wt.), max.	12	10
8	Haven stability factor total on 25 mm, % (by wt.), min.	40	45
9	Porosity, %	38-45	38-45

APPENDIX VII — DRAFT INDIAN STANDARD SPECIFICATION FOR GAS COKE — IS: (TENTATIVE)

Sl No.	Characteristics	Requirement	
		Grade I	Grade II
1	Ash, % (by wt.) (dry basis), max.	22	25
2	V.M., % (by wt.) (dry basis), max.	2	2
3	Sulphur, % (by wt.) (dry basis), max.	0·7	0·7
4	Phosphorus, % (by wt.) (dry basis), max.	0·3	0·3
5	Shatter Index for material over 12·5 mm, % (by wt.), min.	96·0	96·0
6	Porosity, % (by wt.)	40	40
7	Ash fusion temp. °C		
	(a) Initial deformation temp., min.	1240	1240
	(b) Blobbing (fusion) temp., min.	1350	1350

APPENDIX V — INDIAN STANDARD SPECIFICATION FOR FOUNDRY COKE—IS : 4836-1968

Sl No.	Characteristics	Type 1			Type 2		Type 3		
		Gr. I	Gr. II	Gr. III	Gr. II	Gr. III	Gr. I	Gr. II	Gr. III
1	Porosity, % (by wt.), max.	Up to 35	35-45	35-45	35-45	35-45	35-45	35-45	35-45
2	V.M., % (by wt.) (dry basis), max.	0·5	1·0	1·5	2·0	2·0	1·5	2·0	2·0
3	Ash, % (by wt.) (dry basis), max.	Up to 20	20-24	Up to 20	20-24	24-28	Up to 20	20-24	24-28
4	Sulphur, % (by wt.) (dry basis), max.	0·5	0·5	0·7	0·7	0·7	1·0	1·0	1·0
5	Phosphorus, % (by wt.) (dry basis), max.	0·1	0·1	0·15	0·15	0·15	0·3	0·3	0·3
6	Shatter Index for material								
	(a) Over 75 mm, % (by wt.), min.	35	30	30	25	25	25	25	25
	(b) Over 50 mm, % (by wt.), min.	80	75	75	70	70	70	70	70

APPENDIX VI – DRAFT INDIAN STANDARD SPECIFICATION FOR COKE FOR FERRO-ALLOY INDUSTRIES (IS TENTATIVE)

Sl No.	Characteristics	Requirement					
		Gr. I		Gr. II		Gr. III	
		Large	Small	Large	Small	Large	Small
1	Moisture, % (by wt.), max.	5·0	5·0	5·0	5·0	5·0	5·0
2	V.M., % (by wt.), max.	8·0	8·0	3·0	3·0	3·0	3·0
3	Ash, % (by wt.) (dry basis), max.	20	20	21	21	25	25
4	Sulphur, % (by wt.), max.	0·6	0·6	0·6	0·6	0·6	0·6
5	Phosphorus, % (by wt.), max.	0·04	0·04	0·10	0·10	0·16	0·16
6	Reactivity to CO_2, min.	180	180	150	150	120	120

Large, 15-30 mm; small, 5-15 mm.

COALS OF PATHAKHERA AREA, PENCH-KANHAN-TAWA VALLEY COALFIELD—AN APPRAISAL

PATHAKHERA area in the Tawa River basin, known to be coal-bearing for long, has attracted greater attention now because of the installation of a coal-based thermal power station in Satpura by the Madhya Pradesh Electricity Board. The coalfield covers an area of about 54 sq km and is located in Betul district of Madhya Pradesh and is bound by latitudes 22°6′ and 22°11′N and longitudes 78°5′ and 78°13′E.

The Directorate of Geology & Mining, Government of Madhya Pradesh (DGM, MP), carried out exploratory drillings for coal in the area. This work was intensified when the area was taken over by the Indian Bureau of Mines (IBM) and a large number of boreholes were drilled by them in a Priority Block of 7·77 sq km area in the north-central part of the coalfield. The coal cores recovered from these boreholes were studied at the Coal Survey Laboratory, Nagpur, of CFRI.

Coal Seams in the Area

Although the drilling work had proved the existence of ten coal horizons belonging to the Barakar stage, only three of them, viz. Upper Workable, Lower Workable and Bagdona seams, were found to occur persistently and to have good workable thickness for economic exploitation. The IBM estimated a proved reserves of 62·7 m tonnes and indicated reserves of 110 m tonnes for these three seams. The strike of the seams is generally in E-W direction with a northerly dip in a major portion of the block. The disposition of the coal seams encountered during drilling, with the ranges of thickness of coal seams and intervening partings, as given by the IBM[1], is shown in Table 1.

TABLE 1 — DISPOSITION OF COAL SEAMS

Coal seam/parting	Range of thickness (m)
Coal horizon IX	0·30
Parting*	8-9
Coal horizon VIII	0·11-0·90 (usually 0·4-0·5)
Parting*	20
Coal horizon VII (Upper Workable Seam)	0·90-2·53 (usually 1·5-2·0)
Parting*	20
Coal horizon VI (Lower Workable Seam)	1·67-4·48 (usually 3-3·5)
Parting†	6·44-12·77 (usually 8-10)
Coal horizon V	0·06-0·82 (usually 0·3-0·6)
Parting†	3·73-4·90 (usually 4-4·5)
Coal horizon IV	0·14-0·60 (usually 0·2-0·4)
Parting†	8·53-10·11 (usually 9-10)
Coal horizon III	0·16-0·61 (usually 0·2-0·3)
Parting†	2·22-8·53 (usually 4)
Coal horizon II	0·16-0·55 (usually 0·43-0·46)
Parting†	6·13-26·45
Coal horizon I (Bagdona seam)	0·62-2·00 (usually 1·5-1·8)
Parting†	About 50 (with minor coal bands)
Coal horizon IA (encountered in 5 boreholes)	1·26-2·88

*Parting consists mostly of sandstones.
†Parting consists mostly of shales and sandstones.

Exploitation of Coal from Lower Workable Seam

Based on the results of the drilling and the assessment of coal quality from the borehole coal cores by the CSL, Nagpur[2-5], the National Coal Development Corporation (NCDC) opened their Pathakhera colliery in the area for supplying coal to the Satpura Thermal Power Station. The workings of this colliery have so far been restricted to the Lower Workable seam, which is generally of greater thickness. Due to the highly disturbed condition of the seams in the area because of faulting and igneous activity, it is likely that this seam will be the chief source of coal for the present. In order to meet the enhanced requirements of coal of the power station, the NCDC has been contemplating expansion of mining operations in the area and has,

therefore, conducted exploratory drilling in areas outside the earlier Priority Block for proving additional reserves of coal. Evaluation of the data on these boreholes is in progress.

Analysis of Data on Quality

In order to help the planning of expansion of mining operations, a systematic study of the data obtained for borehole coal cores within the Priority Block was undertaken. The highly disturbed condition of the coal seams in the area has caused sharp fluctuation in the quality of coal. It was, therefore, necessary to map the variation in quality of coal in the area in order to plan the production of coal of a desired quality. With this aim in view, seam folio maps for Lower Workable seam have been prepared which can be true guides to the variation in the quality of coal. The iso-ash (Fig. 1) and iso-calorific value (Fig. 2) maps are presented in this note.

The average quality and properties of coal of the Lower workable seam are presented in Table 2. The analyses of the channel samples drawn from the working section in the Pathakhera colliery incline of NCDC[6,7] are also shown.

It is apparent that the quality of coal of this seam varies very widely over the entire area. The seam folio maps presented can, however, help in delineating the zones or patches of uniform quality and in tracing the variation in quality in different directions. On the basis of these seam folio maps, the entire area can be broadly divided into the following zones.

Eastern Zone

This is the area east of the fault F_7-F_7 and north of the fault F_4-F_4. The working incline of the Pathakhera colliery is located within this zone. The thickness of the seam within this zone is generally higher towards the west and lower towards the eastern end.

The percentages of moisture (on 60 per cent RH at 40°C) and ash in the coal of the Lower Workable seam excluding bands in this zone vary between 1·7 and 4·3, and 22·1 and 29·7 respectively. The calorific value ranges between 5400 and 6200 kcal/kg. But in the central part of this zone, the range of ash variation is still closer, from 24 to 27 per cent, with calorific value ranging between 5500 and 5800 kcal/per kg.

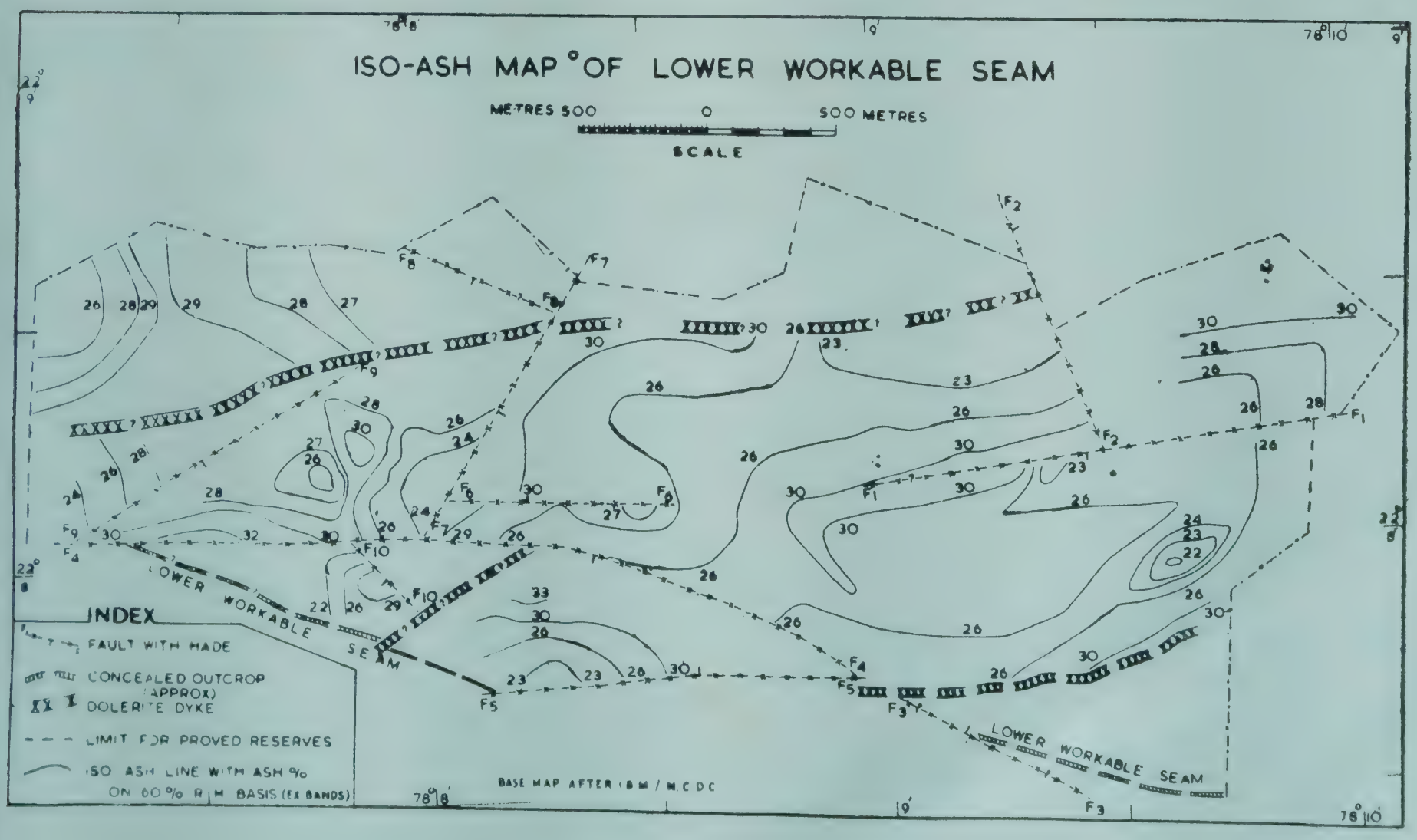

ISO-ASH MAP OF LOWER WORKABLE SEAM
METRES 500 0 500 METRES
SCALE
INDEX
FAULT WITH HADE
CONCEALED OUTCROP (APPROX)
DOLERITE DYKE
LIMIT FOR PROVED RESERVES
ISO ASH LINE WITH ASH %
ON 60 % R H BASIS (EX BANDS)
LOWER WORKABLE SEAM
LOWER WORKABLE SEAM
BASE MAP AFTER I B M / N.C.D.C

FIG. 1—ISO-ASH MAP OF LOWER WORKABLE SEAM

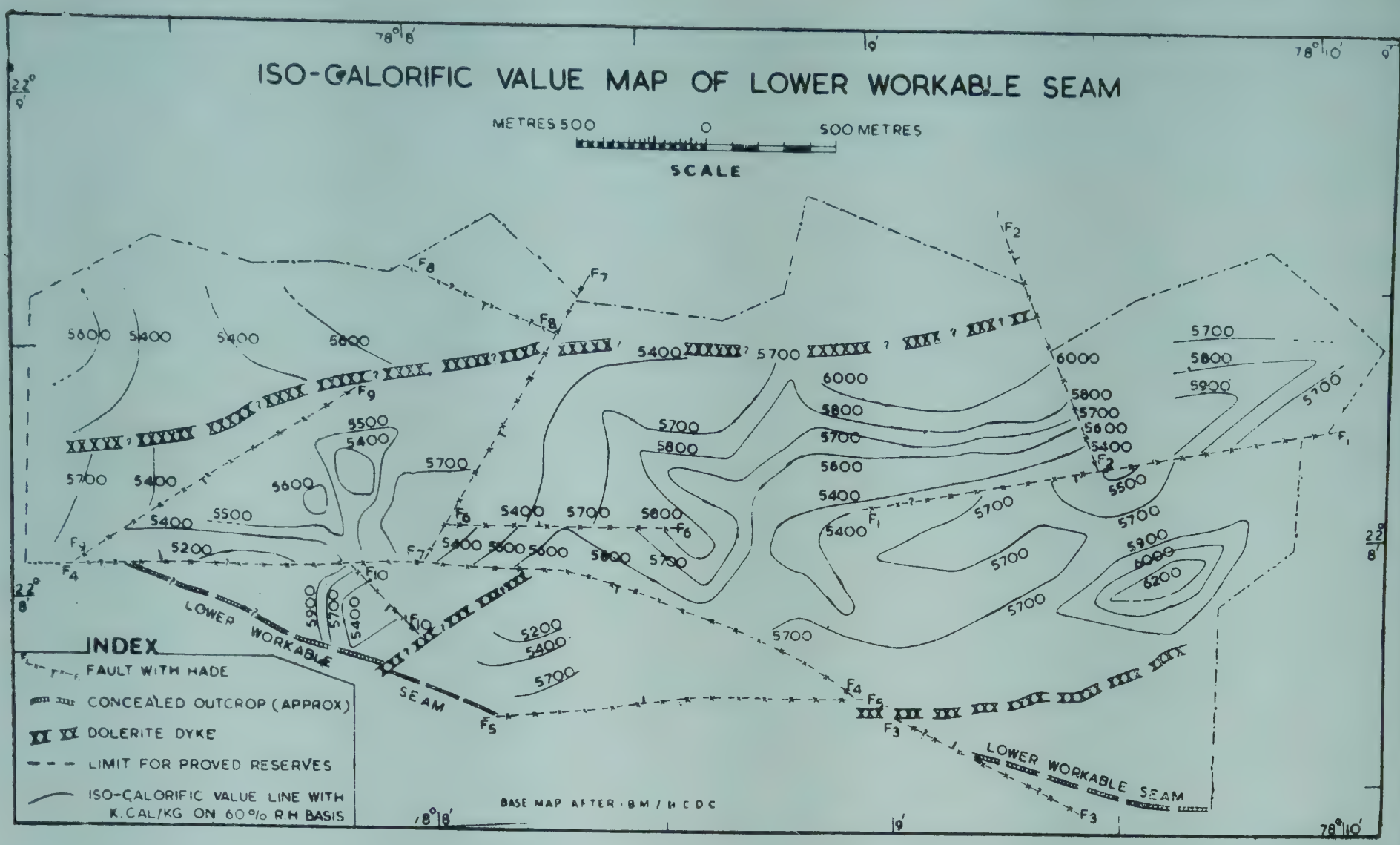

ISO-CALORIFIC VALUE MAP OF LOWER WORKABLE SEAM
METRES 500 0 500 METRES
SCALE
INDEX
FAULT WITH HADE
CONCEALED OUTCROP (APPROX)
DOLERITE DYKE
LIMIT FOR PROVED RESERVES
ISO-CALORIFIC VALUE LINE WITH K.CAL/KG ON 60% R.H BASIS
LOWER WORKABLE SEAM
BASE MAP AFTER B.M / H.C.D.C

FIG. 2 — ISO-CALORIFIC VALUE MAP OF LOWER WORKABLE SEAM

In the south-eastern part of the zone, there is a pocket of low ash coal with ash ranging between 22 and 24 per cent and calorific value between 5900 and 6200 kcal/kg.

In the dip direction (northerly), there is a general trend of decrease in ash with corresponding increase in calorific value. The carbon percentage on unit coal basis is high in this zone and ranges between 85·5 and 88·4; in one case, the value is as high as 89·2. Caking index generally ranges between 7 and 12. Thus, the values in this zone represent the upper limit of the range for the entire field.

Western Zone

This is the area west of the fault F_7-F_7 and north of fault F_4-F_4.

The seam in this zone has generally lower range of thickness than in the western part of the eastern zone. The thickness of the seam in this zone also decreases towards the east.

The percentages of moisture and ash on 60 per cent RH at 40°C basis for samples excluding bands range between 1·8 and 4·7, and 23·7 and 31·0 respectively. In two boreholes, even higher ash percentages (up to 33·5) have been recorded. The calorific value on the same basis ranges between 5000 and 5800 kcal/kg, indicating a lower range than what is observed for the eastern zone coals. The carbon percentage on unit coal and caking index are also low, ranging between 84·4 and 85·7 and from <3 to 8 respectively.

Southern Zone

This is the area to the south of fault F_4-F_4 and is located towards the south-west of the Pathakhera colliery incline. Although the area falling in this zone is small, the seam varies in thickness widely, covering almost the entire range for the whole of the coalfield.

The moisture and ash percentages on 60 per cent RH at 40°C basis for samples excluding bands vary between 3·9 and 4·8, and between 23·4 and 31·6 respectively. The lower moisture values recorded in the other zones are found to be absent in this zone. The ash range is about the same as in the western zone. The calorific value on the same basis is also of a similar order as in the western zone, ranging between 5100 and 5900 kcal/kg. In respect of carbon percentage on unit coal basis and

TABLE 2 — RANGE OF PROPERTIES OF COAL OF THE PATHAKHERA AREA

Nature of samples	Borehole core	Foot by foot prepared overall excl. bands		
		(1964)		(1967)
		(Top sec.)	(Bottom sec.)	(Bottom sec.)
Total thickness of seam (m)	1·67-4·48	—	42	4·0 (approx.)
Thickness of section analysed (m)	1·48-4·48	1·66	2·10	2·66
Total thickness of bands (m)	0·15-0·73	0·10	0·50	0·29
No. of bands	1-5	1	1	2
Analyses (excl. band samples) 60% *RH basis*				
Moisture %	2·2-4·8	2·2	2·3	2·8
Ash %	21·5-36·4	26·6	31·0	26·7
Cal. value, kcal/kg	5070-6165	5790	5420	5790
Total sulphur %	0·3-0·8 (excep. 1·0 and 1·2)	0·5	0·4	0·5
Phosphorus	0·002-0·007	0·007	—	0·004
Unit coal basis				
Volatile matter %	33·9-39·2	37·9	36·6	39·1
Cal. value, kcal/kg	8170-8610	8450	8525	8535
Carbon %	84·4-88·1	85·8	87·1	86·5
Hydrogen %	5·0-5·6	5·5	5·4	5·5
Nitrogen %	1·8-2·1	1·9	2·0	1·8
Sulphur (org.) %	0·3-0·7	0·4	0·4	0·4
Oxygen (by diff.) %	4·5-7·7	6·4	5·1	5·7
Caking index	<3-13	12	7	10
Gray-King LTC assay at 600°C				
Ash (dry) %	24·5-31·5	27·2	31·7	27·5
Tar yield (lit./tonne of dry coal)	90·5-110·0	113·0	97·5	105·0
Coke type				
Coke type	A-D	C	C	C

also caking index, the coals of this zone resemble those from the western zone. The volatile matter (on unit coal basis), as also the yield of tar on Gray-King low temperature carbonization assay at 600°C, record the lowest range of values in this zone, the maximum values being 37·8 per cent and 96·5 litres per tonne of dry coal respectively.

Beneficiation and Other Studies

The generally high and widely fluctuating ash of the coal of this seam will necessitate its beneficiation for proper utilization. Studies on the cleaning characteristics of the coal were carried out on an r.o.m. sample[7]. After crushing the whole coal to below 75 mm, the tests were conducted on the −75+25 mm size fraction which constituted about 67 per cent of the crushed r.o.m. coal.

The results of the washability tests are summarized in Table 3.

It is observed that the washing of this coal after coarse crushing to 75 mm will not prove economic since the yield of clean coal with ash of about 20 per cent is only 17·8 per cent of the raw size fraction (75-25 mm).

In view of the weakly caking nature of the coal, washability tests on coals crushed to smaller size were carried out[8] to explore the possibility of its use in blends. For these tests, borehole coal core samples were crushed to below 3 mm and screened over 0·4 mm. The yield of clean coal with 14-16 per cent ash was found to be rather low, around 30 per cent. Because of poor yield of blendable quality coal, blending this coal with coking coals may not be economically feasible.

TABLE 3 — WASHABILITY CHARACTERISTICS OF R.O.M. COAL

Screen analysis of r.o.m. coal before crushing

Size fraction (mm)	Wt %	Ash %
Over 25	72·1	36·1
Below 25	27·9	33·6
Overall coal	100·0	35·4 (cal.)

Cleaning possibilities of 75-25 mm size fraction of coal crushed to below 75 mm

Unwashed coal		Cut at 1·45 sp. gr.				Cut at 1·50 sp. gr.			
		Cleans		Sinks		Cleans		Sinks	
Wt % whole coal	Ash % (calculated)	Wt %	Ash %	Wt %	Ash %	Wt %	Ash %	Wt %	Ash %
66·9	33·3	17·8	20·2	82·2	36·2	37·9	23·8	62·1	39·1

TABLE 4 — PROPERTIES OF CLEANS AND SINKS

	Clean coal	Sinks
Yield %	27-31	69-73
Analyses on 60% RH basis		
Moisture %	3·6-5·2	2·1-3·6
Ash %	13·9-16·5	37·8-45·0
Cal. value, kcal/kg	6615-6680	4055-4840
Total sulphur %	0·39-0·42	0·29
Phosphorus %	0·003-0·005	—
Analyses on unit coal basis		
Carbon %	83·4-86·2	—
Hydrogen %	5·5-5·7	—
Oxygen (by diff.) %	5·7-8·9	—
Volatile matter %	38·3-40·3	35·6-38·0
Cal. value, kcal/kg	8330-8485	8595-8650
Coke type on LTC assay (gray-king) at 600°C	C	—
Hardgrove grindability index	—	43-50

The quality and properties of the clean coals and sinks were studied. The results are summarized in Table 4.

It is, however, to be noted that it is possible to obtain clean coal of uniformly good quality with low ash percentage and the calorific value lying within a very close range. The corresponding sinks having not a very high ash and exhibiting fairly good calorific value are suitable for power stations. The clean coals can be used for blending for metallurgical coke making.

Washability tests on finely crushed coal were also carried out on channel samples[9]. These samples, drawn from both the top and bottom sections of the Lower Workable seam at Pathakhera colliery, varied in ash from 27·8 to 32·8 per cent. The samples were crushed to below 3 mm and screened over 0·4 mm as in the case of borehole core samples. The percentage yield of clean coal with 13·8-15·7 per cent ash varied between 20·7 and 36·4. The corresponding sinks were found to be of fairly good quality having 35·4-37·6 per cent ash. These data more or less confirm the results obtained on the borehole core samples, with marginal increase in the percentage yield of clean coal.

The ash fusion characteristics of the coal (borehole core samples) under mildly reducing atmosphere were also investigated. This is an important parameter for selecting coals for power generation. The results of these studies are given below:

Softening point, °C	1160-1240
Hemispherical point, °C	1280 to over 1400

These indicate that the ash of this coal has a tendency to soften at a low temperature, which must be taken into account while designing plants for the use of this coal.

Conclusion

From the result of studies presented in this paper, it is observed that the coal of Lower Workable seam is weakly caking with widely varying ash. It is, however, possible to locate zones or pockets of lower

ash range with the help of seam folio maps. It is also possible to trace an increase in the maturity of coal towards the eastern zone of the coalfield. This high ash coal is difficult to wash by coarse crushing but is more amenable to beneficiation on finer crushing. The ash of the coal generally has low softening temperature. The clean coal can be used for blending for producing metallurgical coke and middlings can be used for power generation.

The coal is at present being solely used as a fuel in the Satpura Thermal Power Station situated nearby. Its caking nature and other characteristics suggest its suitability as a constituent of blend for making low phosphorus coke for ferro-alloy industries. For this purpose, the coal has to be beneficiated.

The abundance of minerals like iron and manganese ores in Madhya Pradesh along with coal indicates the possibility of setting up of industries utilizing these minerals. Ferro-manganese manufacture may be contemplated using formed coke of desired specifications prepared out of the low phosphorus weakly caking coals of Pathakhera area by CFRI method after beneficiation.

Acknowledgement

The authors are grateful to the Director, CFRI, for his kind permission to publish the paper. This was earlier presented in a Symposium on Geology and Mineral Resources of M.P., held on 25-28 June 1970 at Vikram University, Ujjain (M.P.).

C. Chatterjee, E. Duraimani, R. N. Kudwalli & K. Y. Shrikhande

References

7. Hunday, A., Rao, V. V. S. R. H., Padmanabhan, V., Suryanarayanan, M. & Rao, B. J., *Report on the Detailed Exploration for Coal in the Priority Block, Pathakhera Coalfield*, Betul District (M.P.), May 1964, I.B.M.
2. *Report of the Regional Coal Survey Station, Nagpur, Report* 1, for the period January-December 1961.
3. *Report of the Regional Coal Survey Station, Nagpur: Part II*, for the period January-December 1962.
4. *Report of the Regional Coal Survey Station, Nagpur: Part II*, for the period January-December 1963.
5. *Report of the Regional Coal Survey Station, Nagpur: Part II*, for the period January-December 1964.
6. *Report of the Regional Coal Survey Station, Nagpur: Part I*, for the period January-December 1964.
7. *Report of work undertaken during* 1967 *by Coal Survey Laboratory, Nagpur.*
8. *Report of the Regional Coal Survey Station, Nagpur: Part I*, for the period January-December 1963.
9. *Report of the Regional Coal Survey Station, Nagpur: Part III*, for the period January-December 1964.

TRENDS IN THE DEVELOPMENT OF LUBRICATING OILS*

Introduction

OVER the last decade the average overall increase of lubricating oils was about 35 per cent the world over; in the same period, however, the production of other petroleum products[1] increased by 100 per cent. Table 1 shows such a trend in the German Federal Republic[2].

Causes of this difference between the rates of increase of the two products are: (a) petroleum products are increasingly employed in many industrial and domestic appliances instead of coal; and (b) long life lubricating oils containing additives have been introduced both in the lubrication of internal combustion engines and in industrial lubricating systems.

It can be seen that although the absolute value of lubricating oil production increases, the importance of these products as related to the total refining capacity increased during the recent years. About 1·2 per cent of the total tonnage of petroleum products were lubricants in 1964 in the German Federal Republic. During the same time, 3 per cent of lubricating oils were used in Austria. The percentage use of lubricating oils is higher in the Soviet Union and Hungary, about 3·8 and 3·5 respectively in the year 1965.

In West European countries and in America most of the new refineries do not have plants for lubricating oil manufacture.

TABLE 1 — PRODUCTION OF DIFFERENT PETROLEUM PRODUCTS IN THE GERMAN FEDERAL REPUBLIC

Product	1956 T/year	1960 T/year	1964 T/year
Gasoline (motor petrol)	3·0	5·4	9·3
Diesel fuel oil	3·1	4·6	6·9
Lubricating oils	0·55	0·65	0·8
Total production of petroleum products	15·3	32·1	66·9

TABLE 2 — PERIOD OF SHARP INCREASE IN LUBRICATING OIL PRODUCTION IN EUROPEAN COUNTRIES

Country	Year
GFR	1953-54
UK	1954-55
Italy	1962-63
Austria	1962-64
Czekoslovakia	1963-66
Hungary	1966-67
Poland	1968-71

In 1965, among the 365 new refineries of the USA, only four contained lubricating oil plants, while in Europe among 286 refineries, there were lubricating oils plants in 11 units[3].

From the statistics of the development of lubricating oil production in several countries, it is seen that in many countries the level of the development shows a sharp increase in lubricating oil production. Table 2 shows the period of sharp increase for several European countries.

The period of the sharp increase is likely to appear in any country when the level of industrialization or of car traffic shows rapid development. A sudden increase of lubricating oil production may, therefore, roughly indicate an overall development of a country[4].

Influence of the Raw Material on the Technology of Lubricating Oil Production

In modern petroleum refineries the quality of the raw material usually does not affect to any appreciable extent the quality of the finished products. In the economy of lubricating oil production, however, yield of the lubricants is related to the nature of the reduced crude employed. Refineries, therefore, use high quality selected crudes for lubricating oil production. Formerly, wax-free crudes were important in lubricating oil manufacture, such as the crudes

*Based on a Lecture delivered at CFRI by Dr Endre Vamos, Head, Applications Research & Development Division, High Pressure Research Institute, Budapest, Hungary.

from Baku, Emba, California, Venezuela, Rumania and others. With naphthenic base oils becoming rare, their use in lubricating oil production is unimportant and are used mainly for the production of low pour point products and arctic oils. Lubricating oils are nowadays mainly produced from wax-bearing crudes with low motor fuel contents and, if possible, with low sulphur contents. Some countries, on account of their geographic situation, some times use for the same purpose even lower quality crudes. The crude imported by the COMECON pipeline to Poland, the German Democratic Republic, Czechoslovakia and Hungary contains sulphur and gives relatively low lubricating oil yields. In spite of this, these countries meet to a large extent their demands in lubricating oils from this crude. Other countries too, for instance, the Soviet Union and Italy, use sulphur bearing crudes in their lubricating oil production. However, the processing of these types of crudes needs special caution. The additives level in such motor lubricating oils has to be higher than usual. In transformer and turbine oils, a higher degree of refining and a higher additive concentration have to be used. Therefore, the cost of lubricating oils, manufactured from sulphur-bearing crudes, tends to be high. In recent years, new, highly paraffinic, low sulphur content crudes have been discovered in Hungary, whereby the production costs of high quality lubricants could be reduced and indigenous crude could be used instead of the imported one for lubricating oil production.

Quality Trends in Lubricating Oil

An important trend in the application of lubricating oil is that lubricating oils of lesser viscosity level are used nowadays. One of the causes of the decrease of average viscosity of oils is that steam cylinder oils are not produced any more. This is a consequence of the introduction of the diesel traction instead of steam engines in railway transport. In the field of transmission lubricants, lower viscosity additive-containing oils are used nowadays instead of the former higher viscosity, additive-free types; so also in air transport where turbine and jet-driven aircrafts are used instead of the former reciprocating motors. The demand in high viscosity oils has decreased. The viscosity level of lubricating oils for internal combustion engines, such as passenger cars and tractors, is also decreasing because of reduced clearances and higher surface finish. In Europe the types SAE-20 and SAE-30, in America SAE 10W/30 or 10W/40 type oils are common. The viscosity distribution in the field of motor lubricating oils in Hungary[5] in 1965 is shown in Table 3.

TABLE 3 — VISCOSITY DISTRIBUTION OF MOTOR OILS FOR INTERNAL COMBUSTION ENGINES IN HUNGARY IN 1965

SAE GROUP	VISCOSITY cst/100°C	PRODUCTION %
SAE 20	6·0	14·8
SAE 30	9·5	54·1
SAE 40	12·0	31·1

Further reduction of the viscosity level is being accepted in Hungary because of the introduction of multigrade oils[15] of the types SAE 20W/40 and SAE 10W/40, starting from 1970.

The average viscosity of passenger car motor oils in the Soviet Union is about 9·5-10 cst for spark ignition motors and 11 cst at 100°C for diesel-driven motors. From the trend of the development in the Soviet Union, such as the mass production of cars of the type Fiat 124, called Shiguly, it may be anticipated that this viscosity level of lubricants will be further reduced by 1971-72.

Technology of Lubricating Oil Manufacture

The basic principles of lubricating oil manufacture have been developed during 1930-40. The process of lubricating oil refining comprises the following steps: vacuum distillation, propane deasphalting, solvent extraction using furfural or phenol and solvent dewaxing using the ketone-toluene-benzene process. Finishing of the refined oil can be accomplished by adsorption or hydrogenation method[6,7]. Lubricating oil plants often include blending facilities.

During vacuum distillation, accuracy of separation is of high importance. In most refineries narrow cuts are processed in order to increase yields of the refining process. Sometimes redistillation units are included in lubricating oil plants for separation of very narrow cuts. In the Soviet Union some of the distillation units comprise two

vacuum columns, while western refineries increase the number of theoretical plates as well as plate efficiency of vacuum columns.

Very high viscosity oils are manufactured from vacuum residues. Hence, in practically all lubricating oil plants of eastern Europe, with the exception of Poland, propane deasphalting units are included. The propane deasphalting capacity of the USA is four million tons per year. As in propane deasphalting units, the solvent to oil ratio is very high, it is essential to select high quality crudes for this process. It is best to use such types of crudes whose vacuum residue contains at least 50 per cent of propane raffinate for a given viscosity level[8]. Efforts for increasing the efficiency of propane deasphalting units by using higher temperature gradients, reflux or RDC columns have not yielded up till now improved results in deasphalting.

For solvent extraction nowadays, phenol and furfural are used exclusively. Other solvent refining processes such as the Duo-Sol, Chlorex, Nitrobenzene or Edeleanu process are used scarcely. Only old existing plants are still operated at low capacities. There is, however, a small field of application for the sulphur dioxide-benzene process for the processing of low viscosity fractions to yield special products, e.g. white oil base stocks.

Recent developments in this field are not concerning the choice of solvent. The efficiency of extraction columns is being increased. One of the most important developments in the field of furfural refining is the use of the RDC columns[3,9]. New furfural refineries in England and in some east European countries use such columns which give sharp separation and have small dimensions (e.g. the solvent refinery in Bratislava). In phenol extraction units this method cannot be applied because of emulsifying tendencies of the phases. There is a possibility to increase the efficiency of such systems by using pulsating columns[7]. Reduction of corrosion and solvent losses could be achieved in furfural phenol extraction plants.

For dewaxing, practically only the ketone-toluene-benzene process is now used. In some old plants, the almost obsolete methods, such as cold filtration, propane dewaxing and Bary Sol dewaxing are still in use; however, the overall capacity of these plants is less than 5 per cent of the world dewaxing capacity. In America and western Europe, methyl-ethyl-ketone (MEK) is used along with aromatic hydrocarbons, while eastern European countries use the acetone-benzene-toluene (ABT) process. Substantial changes in technology have not occurred over the past 10 or 15 years. The use of single solvent systems, using a higher ketone, such as methyl-isobutyl-ketone (MIBUK), is being examined.

There are two new methods for elimination of normal parafins from hydrocarbon mixtures. These are the urea dewaxing and the molecular sieving methods. These, however, are mainly used for medium distillates and only in Poland, efforts are being made to use one of these methods for the production of low pour point transformer oils.

For finishing operations, till recently, adsorption processes were used. Three main types of adsorption processes are: (a) low temperature contacting, (b) hot contacting, and (c) percolation. In Hungary and in middle Europe, hot contacting is used to a considerable extent. In the technique of percolation, some development has been noted in the last 15 years. Instead of the batch process, continuous counter-current percolation is used in many plants[6,9], especially in America and in the UK. However, since 1965, adsorption processes are being gradually displaced by hydrofinishing. The capacity of such plants in America reaches about 70 per cent of the overall lubricating oil finishing capacity. In western Europe too, this process is rapidly displacing the contacting process. In new refineries usually hydrofinishing is used exclusively. The same trend has been seen in eastern Europe where in new plants the majority of oils is finished by hydrogenation methods, if sufficient hydrogen is available in the plant.

Sulphuric acid treating units are usually not installed any more. In existing units, however, such plants are still operated. Even in the United States, 9 refineries operate sulphuric acid treating plants[3]. It can be expected that this method will not be used to any considerable extent in the future. Some specialities may still require sulphuric acid treatment in the absence of any better process.

It can be seen that from 1935 up to 1965, there was a relative stagnation in the development of lubricating oil refining technologies. Notable change is marked

only in the last 5 years. Hydrogenation is mainly used in the finishing of lubricating oils. It can also be used as an additional technology along with extraction. It is even possible that hydro-treatment will replace to some extent solvent extraction. In principle, there are three ways of introducing hydrogenation processes in the scheme of lubricating oil manufacture, viz. (i) before the extraction, in order to increase yields of the extraction; (ii) instead of solvent extraction hydrotreating may overtake the functions of solvent refining; and (iii) after the solvent treating instead of contacting, hydrofinishing may be practised.

It seems even possible that streams from hydrocracking units may also contribute to lubricating oil production. Up till now, however, no hydro-cracking units are in operation in Hungary and middle Europe.

High pressure hydrogenation technology for the production of motor fuels are at present out of date. However, some countries in which such old plants exist, such as Czekoslovakia, the German Democratic Republic and Poland, use the existing reactors for the refining of lubricating oils. One of the causes of increased interest in hydrotreating methods is that many countries have to use sulphur-bearing crudes for lubricating oil manufacture. Hydrotreating methods yield lower sulphur content products than solvent extraction.

Additives

Contrary to the relative stagnation in manufacturing technology, qualities of motor lubricating oils have rapidly changed over the last 15-20 years. Besides the tendency to lower the viscosities, the degree of refining is being increased, which can be expressed in terms of viscosity index. From 1950 to 1970 in the United States, the viscosity index of the base stock was increased from 80 to 100. In Europe, the increase was not so substantial. In east European countries the viscosity index of base stocks during the same period was increased from 70 to 85. An even more important change in lubricating oil quality was the use and the development of additives. The first cause for the development of additives was the extended use of high speed and supercharge diesel engines and the ever increasing proportion of medium or high sulphur content gas oils[10].

Nowadays, practically all motor lubricating oils in the United States and in Europe contain additive and even industrial oils, e.g. gear oils and turbine oils, have to be blended with one or several additives. The use of additive blended oils seems to be increasing. Oil qualities higher than the HD level, such as the types Supplement 1 and for super charged diesel motors, the categories of Series 2 and 3 have been introduced. These types of oils with higher additive levels have to be used because of the higher mechanical and thermal load of the engines and the higher sulphur content of the gas oil.

In the United States, high level additive containing oils have been introduced for spark ignition motors too. This is a special problem in America where high performance cars are used. In their motor, temperature usually does not attain equilibrium conditions and, therefore, the problem of cold sludge formation has to be faced.

Bench tests have been developed for estimation of performance of motor lubricating oils. The most characteristic tests used in Europe are the Petter and Fiat 600 motor tests. In America, the Caterpillar and other methods[14] are used.

In the last 10 years, the use of multigrade oils became common in Europe. These contain viscosity index improver and as a consequence they may be used under highly changing ambient temperature conditions. Such multigrade oils are used in western Europe for spark ignition and diesel motor lubrication. In eastern Europe and in Hungary they are mainly used for spark ignition motors.

For spark ignition motors in America and in western Europe, oils containing 4-5 per cent of additives are used. These oils are mainly of the detergent and inhibitor type. In diesel motor oils of the HD and Supplement 1 category, the additive concentration is about 4-6 per cent, in the categories Series 2 about 5-7 per cent and in the categories Series 3, about 12-16 per cent. Multigrade oils require for the same categories an additional amount of polymer additive of about 4-10 per cent. In some oils, corrosion reducing and anti-foam additives are used. As of late detergents are used in spark ignition engines too, there is a tendency to change from ash containing detergents to ash-free additives of the succinimide type. In east European countries the average additive contents of motor

TABLE 4 — TYPES OF LUBRICATING OIL ADDITIVE USED IN HUNGARY

Type	Application field	Chemical composition
Ash containing detergents	Diesel motors and spark ignition motors	Synthetic Ba sulphonates
Low temperature oxidation inhibitors	Industrial oils (e.g. turbines)	Di-tertiary-butyl-cresols
High temperature oxidation inhibitors	Internal combustion engines and industrial oils	Zn-di-alkyl-dithiophosphates
Viscosity modifiers	Multigrade motor oils and hydraulic oils	Polyalkylmethacrylates
Oiliness improvers	Textile and metal working oils	Fatty acid glyceride
EP additives	Gear oils and metal working oils, textile oils and lubricating greases	Cl and S containing additives as well as MoS_2
Pour point depressants	Low temperature lubrication	Xylenole-ethers
Antifoam additives	Diesel motor oils, turbines, etc.	Alkyl-siloxanes
Corrosion inhibitors	Diesel motor oils, turbines, metal cutting oils	Organic bases

lubricating oils is slightly lower. However, especially in Hungary, efforts are being made to attain the additive level of middle European countries.

It can be seen that the additive concentration in motor oils is ever increasing. Even the remaining hydrocarbon component of the oil is being replaced by high viscosity index ester type synthetic oils, especially in Italy and Austria, for multigrade motor oils. For instance, multigrade motor oils of the latest type contain 40-50 per cent synthetic oil and 6-12 per cent of various additives. In east European countries the minimum additive level corresponds to the HD level; average additive contents of oils is 4-6 per cent. In Hungary the additive concentration is a little higher.

While the majority of lubricating oils is used for lubrication of internal combustion engines, still a substantial percentage of lubricating oils is used for industrial purposes, e.g. for hydraulic systems, turbines and other industrial lubricating systems. In this section of industrial lubricating oils, a rapid change can be seen. Instead of 'once through' lubricating systems, circulation systems are used and, therefore, the importance of oxidation stability is increasing. In all the fields of industrial lubrication, higher speeds and loads are being encountered and longer life-time of the oils is required. For this purpose, highly refined oils, containing at least oxidation inhibitors are marketed for this purpose. In gear lubrication and metal machining oils, oiliness improvers and EP additives are required and even the use of viscosity index improvers has been extended to industrial lubricating oils.

By increasing oxidation and thermal stability of oils, long life or even life-time lubricants are produced. These are not, however, yet in use in Hungary. Along with EP additives for many oil types corrosion inhibitors have to be used and so the composition of industrial oils becomes almost as sophisticated as that of motor lubricating oils. The additive level in industrial lubricating oils is also increasing. In Hungary, at present 85 per cent of all lubricating oils, comprising motor oils and industrial lubricants, contain some type of additive. Mostly organic compounds are used, but the use of graphite and MoS_2 is also increasing, especially in industrial lubricants. Types of additives used in Hungary are listed in Table 4.

Finally, it may be mentioned that in industrial lubrication, the use of some synthetic oils such as polyethers and silicones are increasing along with highly refined hydrocarbon oils.

Reviewing the trends in the two main groups of lubricating oils, it can be seen that in the last 20 years the average degree of raffination and the percentage of additives have increased. The composition of lubricating oils is nowadays complex and most of them contain several components of different types. Another noticeable trend is the development of multipurpose additives containing several functional groups, to reduce interaction of different additives used in one oil. Due to all these developments increase in the lubricating oil manufacture correspond to the manufacture of heavy organic chemicals and organic intermediates. Hydrocarbons are nowadays only

one of the components of the oil. Thus, in some countries, refineries only manufacture base stocks and finished products are blended with additives and synthetic oils in special lubricating oil blending plants.

ENDRE VAMOS

References

1. *Petroleum Press Service*, **28** (1961), 470.
2. *Erdol & Kohle*, Nos. 1-10 (1955-65).
3. NELESON, W.L., *Oil & Gas Journal, International*, **6**, 70.
4. SIMON, P. & PECELI, B., *MTA. Kem. Tud. Oszt. Kozl.* (Publications of the Hung. Acad. Sci.), **22** (1961), 211.
5. SZAVA, N. & VAMOS, E., *Magy. Kem Lapja* (*J. Hung. chem. Soc.*), **1** (1967), 33.
6. PRINZLER, H., Enfuhrung in die Technologie des Erdols, Leipzig, 1961.
7. VAMOS, E., *MTA Kem. Tud. Oszt. Kozl.* (Publications of the Hung. Acad. Sci.), **22** (1964), 234.
8. VAMOS, E. & KOIL, G., *Chem. Tech.* (*GDR*), **16** (1964), 9B and (1964), 539.
9. *Petroleum processing*: I (1957), 139.
10. SZAVA, N., *MTA Kem. Tud. Oszt. Kozl.* (Publications of the Hung. Acad. Sci.), **22** (1964), 221.
11. BEUCHLER, COX *et al.*, *Proceedings of the VI World Petroleum Congress*, Sect. 6, No. 16, 1964.
12. ROST, R., *Proc. of the VI World Petroleum Congress*, Sect, 6, No. 5, 1963.
13. O.'CONNOR, F. & BOYD, E., *Standard Handbook on Lubrication Engineering* (McGraw-Hill Co. Inc., N.Y.), 1968.
14. GEEL, P. K. & KRISHNA, M. G., *Proc. of the Seminar of Modern Trends in the Production and Utilization of Lubricants*, (1971), 91.
15. VAMOS, E., Application experiences with multigrade oils, *Proc. of the Congress on Lubricants, Sofia* (*Bulgaria*), 1970 (in press).

Spotlight

ON SCIENTIFIC ACTIVITIES

Ortho-phthalonitrile from Ortho-xylene

Phthalonitrile is an important intermediate, capable of undergoing addition and substitution reactions to yield a range of organic compounds which constitute the basic raw materials for the dyestuffs, adhesives, polyamides, resins, synthetic fibres, food preservatives and ethical drugs. Phthalonitrile is also the key intermediate for the manufacture of phthalocyanine pigments. Hydrogenation of the phthalonitrile results in the production of xylene diamines which find use in the manufacture of high quality thermally stable resins.

Introduction of the nitrile group into aromatic molecules normally involves a whole sequence of reactions, as for example, halogenation or sulphonation followed by diazotization and coupling with cuprous cyanide or alternatively oxidation to the relevant carboxylic acid group and followed by conversion to the amide and dehydration to the nitrile.

Research has been conducted at the Central Fuel Research Institute, to develop a continuous process* for the production of ortho-phthalonitrile from ortho-xylenes through catalytic vapour phase ammoxidation or oxidative ammonolysis.

The transformation is carried out in this case in a reactor partly filled with the catalyst supported over unglazed porcelain beads. The reactor is heated to a definite temperature where it is maintained for predetermined time before the raw materials are fed to it. Primary air is drawn through the ortho-xylene well previously heated to such a temperature and maintained thereto that the desired proportion of ortho-xylene is entrained all the time. The requisite amount of secondary air to make up the appropriate total air to feed ratio is fed through a bypass. Ammonia is fed through a separate feed line and mixed with xylene and air in required ratio in a surge tank.

The reaction products are collected in three sets of condensers, the first cooled with air, the second with circulating water at 10°C, and the third under crushed ice. The major part of the dinitrile was trapped in the air condensers, the ice-cooled traps holding the residual dinitriles along with traces of unreacted xylene. Xylene is isolated from the outgoing stream by refrigeration effecting near quantitative recovery. The flowdiagram of the process is given in Fig. 1.

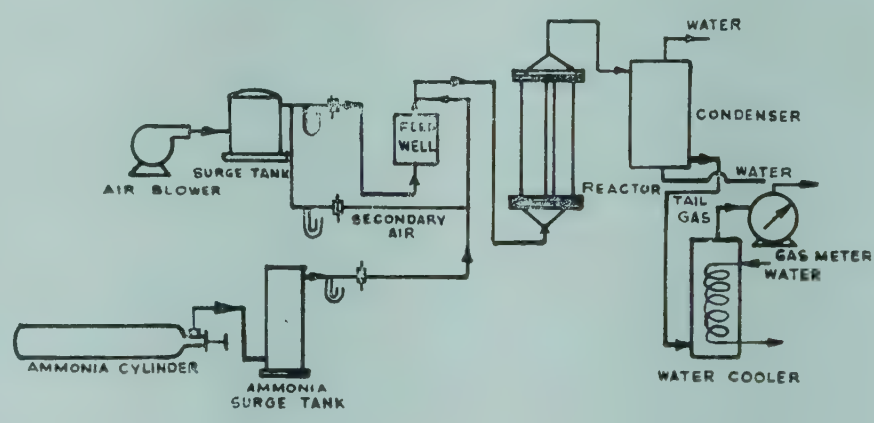


Fig. 1 — Flowdiagram of the process

Phthalonitrile obtained per pass is 70 kg per 100 kg of xylene charged. With recycling of the unreacted feedstock, the yield is higher.

The novelty of the CFRI invention is that the process dispenses with the need for the expensive chemicals and enable operation of the process on a continuous basis to give a pure product. Raw materials needed for the process and chemicals required for catalyst preparation are all available indigenously or against rupee payment.

*Under patent.

Pine Oil as a Frother for Coal Flotation*

The need for beneficiation of fine coal and washery slurries arises out of the realization that the coking coal fines often contain valuable petrographic components indispensable for good coke making and that allowing these dusts to go down the rivers will pollute the water and cause health hazards. Moreover, the recovery of washery fines has a salutary effect on the overall economics of coal washing.

The established method of recovery of fines from coal-slurries is by froth flotation. In this process, besides a collector, a frother is used whose function is to produce voluminous froth of desired size and stability, so that the coal particles are trapped and buoyed up so that they can be removed from the flotation unit. In selecting a suitable frother, the points which are taken into consideration are that it should be cheap, effective at minimum dose and readily available. Pine oil has fully established its efficacy and superiority over many other frothers in foreign countries. Experiments at Central Fuel Research Institute aimed at judging the comparative efficiency of pine oil (both imported and indigenous) and many other frothers in presence of various collectors when applied to natural and synthetic slurries.

The study led to the following inferences: (i) flotation efficiency of pine oil of different grades and of the other frothers are considerably enhanced when used in conjunction with suitable oily collectors; (ii) commercial pine oil, which is understood to be the cheapest of the grades, now available in the market, gives comparable if not better results when added at a dose between 0·15 and 0·2 kg per ton of dry fines; (iii) although commercial variety of pine oil has good frothing properties, the flotation efficiency can be considerably influenced by the nature of the collector used; (iv) judging by the combustible matter recovery per cent, pine oil when used in combination with a suitable collector, gives the best performance followed in order by that obtained with methyl amyl alcohol and cresylic acid; and (v) the flotative power of indigenous pine oil is quite comparable to that of imported pine oil.

It can, therefore, be concluded that pine oil has the potentiality of becoming the most effective frother. Its consumption is low. A projection of future demand and production shows that the material will not be in short supply.

*Based on the paper "Potentialities of the use of pine oil as a frother for coal flotation in India", by G. G. Sarkar & B. B. Konar, presented to the Symposium organized by SYMPINE at Delhi during 13-14 April 1971.

Mechanism of Coal Pyrolysis and Industrial Practice†

Production of coke for blast furnace use from coking coals or equivalent coking blends is a well-established technology. But the fundamentals of pyrolysis are still to be fully elucidated. With the help of the studies, conducted at CFRI on the structure of coal and mechanism of coal pyrolysis, a postulate is put forward which visualizes the course of reactions involved in high temperature carbonization and to explain the reasons for divergence in the nature and yields of products from laboratory assays.

Two stages in coal pyrolysis have long been recognized. The first at and up to 600°C is the primary stage and the second up to 1000-1050°C is the secondary stage. Earlier, CFRI studies have shown that during primary stage, aromatic carbon fraction is effectively retained intact yielding semi-coke or char, while hydroaromatic carbon goes to the formation of primary tar and the aliphatic structures to the formation of gases. Recently, the validity of these postulates with respect to primary pyrolysis (at and up to 600°C), has been critically examined. It has been noted that the mechanism is strictly followed only under ideal conditions, e.g. in fluid bed and transport reactors (i.e. where time of residence of the primary volatiles within the incipient coke mass is the shortest).

The departure of Gray-King Assay (600°C), in the way of 20-30 per cent lower yield of tar in relation to the theoretical yield (corresponding to hydroaromatic carbon content), is shown to be due to coke-tar interaction. This appears to be a function of the thickness of coal bed, rate of heating, etc. Greater the thickness of coal bed,

†Based on a paper "Mechanism of coal pyrolysis in relation to industrial practice", by B. K. Mazumdar & N. N. Chaterjee, presented before the Coke Oven Managers' Association Technical Meeting on 29 August 1970. The paper was later awarded a Silver Medal of the Association.

greater is the degree of such interaction and consequent inhibition of tar formation, resulting in proportionate increase in coke yields. Coke and tar yields are thus found to be inter-convertible, depending on the conditions of primary pyrolysis but having virtually no effect on the proportion of carbon consumed for gas formation.

Extension of the above findings to the high temperature industrial carbonization practice indicates that higher yields of coke (usually 7-8 per cent higher, on dry basis) over the theory and correspondingly lower yields of tar are due to the same coke-tar interaction and consequent inhibition of tar formation. The suppression can be to an extent as high as 75 per cent, primarily because of massive thickness of coal bed in coke ovens. The fixation of 'tar-forming' carbon (hydroaromatic according to the theory), does not appear to be due to cracking of tar but occurs during the primary stage of pyrolysis (below 600°C), perhaps through condensation-polymerization reactions within the coke mass (mechanism of which is ill understood at the moment). The process appears to be, at least, far too different from what has been hitherto believed as cracking reactions. The above conclusion is also supported by a study of the distribution of carbon in gas. These studies have also suggested that the cause for occasional carbon deposition, on the exposed hot walls and other regions of coke ovens, must be something else other than cracking of tar and gas.

A Conceptual Structure for Assam Coal*

Assam coal was chosen for a recent study on coal structure at CFRI in view of its highly caking nature notwithstanding its low carbon content (75-80 per cent). Another peculiarity is that it contains high amounts of sulphur.

Infrared spectra and the n.m.r. spectra of the coals and their extracts in benzene and γ-picoline were obtained and analysed. While comparing the 3020 cm^{-1} band region corresponding to aromatic carbon-hydrogen stretching frequencies and the 1600 cm^{-1} band originating from the C=C aromatic ring breathing modes in infrared, an anomaly in intensities could be observed. The 1600 cm^{-1} band was found to be strong, broad and diffuse in all cases pointing to the presence of an assortment of aromatic ring structures of varying sizes, constituting, presumably, the core of the structure. On the other hand, the low intensity of the aromatic C-H stretching vibrations of the coals when viewed in the light of relative intensities of 3020 cm^{-1} and 1600 cm^{-1} bands of several model aromatic compounds, leads to the assumption after allowing for variations in intensities on symmetry consideration that the atomic proportion of the aromatic carbon is high, relative to aromatic hydrogen and the low aromatic hydrogen is due to the majority of the aromatic carbons being located in structural environments, where the fourth valency of the carbon is satisfied by alkyl groups or other functional groups. Structurally speaking, this means a basic core of an aromatic structure, perhaps more angularly condensed than otherwise.

A comparison of the spectroscopic data on the coals and their γ-picoline extract (10 per cent of the coal) supports the view that they are structurally similar, there being no marked difference in their absorption spectra. From the n.m.r. spectra of the extracts, three categories of non-aromatic hydrogen, viz. (a) hydrogens carried on carbon atoms alpha to an aromatic ring, (b) hydrogen carried on alkyl carbon atoms, other than those which are alpha to an aromatic ring, less methyl or hydrogen in tertiary butyl and isopropyl systems, and (c) hydrogen on methyl groups occurring as part of tertiary butyl and isopropyl systems, have been observed and their relative ratios have been found as (a):(b):(c)::2·54:3·54:1.

Since the non-aromatic hydrogen appears to predominate primarily as methyl hydrogen and next in order of importance as methylene hydrogen, the presumption that there is less than one (about 0·8) non-aromatic carbon atom for every two non-aromatic hydrogen is justified when the contribution of the tertiary butyl carbon atoms which do not carry any hydrogen is allowed for.

Ultimate analysis of the γ-picoline extract of coal from Baragolai gives the atom per cent ratio of carbon to hydrogen as 6·55:6·16 (roughly 1:1). Since in the non-aromatic

*Based on a paper by N. V. R. Appa Rao, G. S. Murty, H. S. Rao & A. Lahiri presented to CFRI symposium on chemicals and oil from coal, 6-8 Dec. 1969.

part the evidence would appear to be consistent with a ratio of more than two hydrogen atoms (about 2·5 or so) for every carbon atom, it follows that in the aromatic part only a fraction of the aromatic carbons carry hydrogen atoms, thus leading to the conclusion that the major part of the aromatic carbons are present as carbon atoms in fused rings, with all four valencies being satisfied by participation with other carbon atoms. Assuming that the extract is structurally related to coal, the evidence would clearly indicate a core structure of dimensions sufficient to make the fused carbon atoms proportionately high, with comparatively small (i.e. one, two and three carbon with more of one than two and three carbon) alkyl substituents.

The carbonyl band has been observed in many of the coals. The bands are not different from those of the more mature coals of the Jharia coalfield. Another notable observation is that the substantial carbon aromaticity is inconsistent with a coal structure which is not largely planar.

Based on the arguments presented above and other available evidence on the nature of coal, an attempt has been made to evolve a conceptual structure of "Stringed Rafts in an Eddy" for Assam coal, in which largely planar angularly condensed aromatic systems constitute the 'Rafts' and the bridges constitute the 'Strings'.

The above structure may help in selecting the most effective catalyst for the hydrogenation of Assam coals for the production of oil. For the production of low boiling products and middle distillates, it appears that hydrogenation under mild pyrolytic conditions should hold more promise than at lower temperatures.

The postulate of a relatively large, angularly condensed aromatic core with short alkyl substituents can, under conditions of hydrogenation that exclude cleavage, lead primarily only to two kinds of products: first, a heavy oil residue corresponding to the per-hydrogenated aromatic core, and second, light hydrocarbon gases (C_1-C_4) with methane as a major component.

Notes & News

Committee and Meeting

A meeting of the Scientific Committee of CFRI was held at CFRI on 7 April 1971 under the Chairmanship of Mr S. K. Nargundkar, Executive Adviser, East Indian Coal Co., Jealgora.

With regard to the CSIR's suggestions to effect economy by way of utilizing existing equipment for the future plan project, the Committee observed that CFRI had established a broad base which enabled it to undertake new projects with minimum of costs.

Discussing the question of linking up projects with users, the Committee appreciated that whenever possible, the Institute had attempted to involve the manufacturers, consultants or entrepreneurs, both in the public and in the private sectors, with the projects in hand. The Committee was, however, of the opinion that under Indian conditions, it would be necessary to demonstrate the process before entrepreneurs could be made interested in investments in further development.

The Committee then discussed the annual report of the CFRI for 1970-71 and scrutinized in detail many of the programmes, especially those with regard to active carbon, electrodes, formed coke, synthetic chemicals and oil from coal. It noted that the CFRI had been working on a new concept for pre-reduction of iron ore with gases produced from non-coking coals. The Committee discussed in particular the efforts of the Institute with regard to production of gas by various techniques and for various purposes such as for synthesis, fuel gas, pipeline gas, etc.

The Committee accepted the revised priority programme for the IV Plan and agreed that this was in keeping with the techno-economic developments in the country. The members particularly emphasized the need for speedy approval of funds for the two major national projects, viz. (i) production of formed coke including fluid bed carbonization, and (ii) production of chemicals and oil from coal. They noted with interest the breakthrough achieved in demineralization of coal by a new process developed by the Institute, which opened up possibilities of utilizing the peninsular coals for solvent extraction, hydrogenation, etc.

Discussing and approving the programme of work for 1971-72, the Committee observed that in view of setting up of several petrochemical complexes in the eastern region in the near future and in view of the expertise of the Institute in many fields of catalytic synthesis, a part of the Institute's activities should be deliberately oriented towards production of chemicals with raw material derived from both coal and petroleum. It was noted that in many cases the raw materials were identical, such as the aromatics, but the quantity and supply were likely to be greater from petro-chemical sources. The Committee was particularly happy to find that the Laboratory was well equipped to undertake oriented basic studies in these fields. It was suggested that wherever possible, while developing these techniques, collaboration with consulting engineers or likely entrepreneurs may be secured in principle or in practice.

■ On invitation, Shri G. G. Sarkar, Assistant Director, CFRI, delivered a talk* on " Coal Washing Practice in India " at the Annual Session of the Indian Institute of Mineral Engineers, held at Bangalore on 2 January 1971, concurrently with the Indian Science Congress Sessions.

Speaking on the need of washing Indian coals, Shri Sarkar said that in early forties the planners of iron & steel industry realized that high ash Indian coking coals would have to be washed for meeting the stringent specifications of iron and steel industry, as low ash coking coals were almost exhausted.

Tracing the history of coal washing research and practice in India, Shri Sarkar pointed out that in 1944, the Council of Scientific & Industrial Research (CSIR) sponsored a research scheme on coal washing under the auspices of the Fuel Research Committee. Subsequently, the project was transferred to the Central Fuel Research Institute. Since then, CFRI has been studying the problem from various angles and the knowledge gathered has led to the preparation of feasibility reports of all the public sector commercial washeries. The Institute has further aided these projects in scrutiny of tenders, assessing the performance of washeries and in undertaking trouble shooting jobs in the plants.

Reviewing the present position, Shri Sarkar said that India has today 15 commercial coal washeries with an installed capacity of over 6500 tonnes of coal per hour corresponding to over 27 m tons of raw coal per annum including the only non-coking coal washery at Nowrozabad (capacity, 125 tons per hour). The individual capacity of these washeries varies from 70 to 800 tons/hour.

Shri Sarkar maintained that the additional coking coal requirements of the Fourth and subsequent plans would have to come from coals having moderately difficult to extremely difficult washing characteristics. These coals would have to be crushed to finer sizes (13 or 10 mm) prior to washing. It might also be necessary to first deshale the whole coal and then treat the crushed cleans for the recovery of cleans and middlings. The treatment of the fraction above 0·5 mm would be in dense medium cyclones and the slurry below 0·5 mm in autogenous cyclones or flotation cells. In this connection, Shri Sarkar indicated the vast potentiality of the CFRI patented process (oleoflotation) for simultaneous upgrading and dewatering fine coal which poses problems in such operations.

*This lecture formed the subject matter of a paper entitled " Coal washing practice in India — A survey in retrospect and of prospect", by G. G. Sarkar & S. Ranga Raja Rao, published in the Special Republic Day Issue of the *New Sketch*, 1971.

Regarding the growing clamour in favour of importing coking coal on the grounds of inadequacy of indigenous resources and increasing cost, Shri Sarkar opined that reduction of cost of washed coal was likely in future when all our coals would be processed through pit-head washeries and standard washing circuits incorporating indigenous machineries would be adopted. On the other hand, import and transport of imported coal would not only create problems of storage and degradation but also lead to petrographic imbalance when blended with inferior Indian coals and this would make production of good coke difficult. Moreover, indigenous technical know-how is now available which enables reduction of ash percentage of most Indian coals down to ash level generally found in imported coals. Lastly, steel plants, based on imported coal, would always have to face the possibility of sudden shut-down if the supply gets cut-off due to international crises and emergencies.

■ A meeting of the Coal Advisory Council of the Department of Mines & Metals was held in New Delhi on 19 December 1970 to discuss the various aspects of coal and coke industries *vis-à-vis* iron & steel industry and in particular assessment of coal demand for the Fourth Plan. The Director, CFRI, was represented in the meeting by Mr A. K. Moitra, Assistant Director. Hon'ble Union Minister for Petroleum & Chemicals and Mines & Metals, Dr Triguna Sen inaugurated the Council Meeting.

Reference was made to the variable assessment of demand figures resulting in the newly created production capacity becoming idle or causing continued accumulation of coal at pit-head. A firm assessment, so that production could be planned well in advance, was considered necessary. Shri Ranchor Prasad of NCDC suggested the need for a long-term and a medium-term assessment in this connection. With regard to the controversy of excess supply of washed coal, Shri K. S. R. Chari of the Department of Mines & Metals clarified the position by stating that even according to Dutt Committee's recommendations, some amount of coking coals were bound to be non-utilized due to their bad quality and non-availability of washing capacity. The Minister suggested that to make the demand figures more realistic, the consumers, like steel plants and railways, must indicate their firm demand. He also suggested the introduction of a bonus/penalty clause in the supply agreement with consumers for guaranteed supply and off-take of the contracted quantity.

Regarding non-coking coal, it was noted that the fluctuations in estimate of demand existed with this type of coal also, particularly in the State Sector. The position was further worsened by the inadequacy of transport facilities and diversion of a part of a coking coal for non-metallurgical use. To enable the Railways to plan their movement, Shri R. Lall said, it was necessary to give them a break-up of the demand fieldwise. The fluctuation in demand was ascribed to the multiplicity of suppliers and consumers. Shri Chari said, while it would be and had been possible to identify and control the demand of the large consumers, fluctuation in demand/supply would not be much in case of small consumers. Attention was also focussed on the problem of inadequacy of wagon supply, and the unsatisfied demand of brick burning industry due to Railways' reluctance in the movement of inferior grades of coal.

Shri V. P. Sawhney of Railways stated that for transport planning they needed directionwise movement figures besides the fieldwise break-up. Shri K. K. Ray, Coal Controller, pointed out that the required data for calculating the same had been collected and the figures would be communicated as early as possible.

As to non-fulfilment of demand of brick-burning industries, the Railways' representative pointed out to the unsteady demand of wagons during slump and boom periods. Dumping of coal in slack season and its use in peak periods, according to him, might ensure a steady demand of wagons throughout the year. Appealing to the Railways to improve the wagon supply, attention was drawn to tremendous loss in terms of deterioration in quality that would arise due to the dumping of coal.

Being aware of the critical situation prevailing in coal industry due to reduced off-take of coal, it was made known that the Railways have constituted a committee to review the situation periodically.

It was felt by the private sector that they were being denied the share of creating new capacities for meeting the additional demand of non-coking coal. It was mentioned that no new capacity, either in the public or private sector, was allowed except those needed for specific purposes.

■ In his Presidential speech at the Fifty-eighth Annual General Meeting of Indian Mining Federation, held at Calcutta on 26 March 1971, Shri H. N. Mookherjee apprehended that Fourth Plan coal production target of 93·5 million tonnes would have to be cut down to 85 million tonnes. As major problems of the coal industry, he enumerated the declining profitability owing to unremunerative price paid by the consumers, the crisis in rail transport, lack of adequate explosives and iron & steel materials as well as the indifferent attitude of the governmental authorities. Shortfall in wagon supply, he said, had compelled the consumers to reduce their demand and in some cases completely close down their operations. As a result, stock had piled up in the pit-head and working capital got locked up.

An aftermath of decontrol and accumulation of stock at pit-head had been the unremunerative price coal is fetching. Pointing to another ill effect of decreasing off-take of coking coal, especially of inferior variety of coking coal, Shri Mookherjee said that unless appropriate measures were taken to prevent the collieries mining such coals from closing down, the steel plants would have to face a crisis of coking coals in future.

He also felt that the industry was being denied not only of adequate price but also the necessary raw materials such as iron and steel, explosives, etc., for its routine operations. The production of the only explosive factory earmarked to supply the needs of the coal industry, was far below the demand.

Mr Mookherjee urged the government to reconsider its fuel policy and to modify if not fully give up its dieselization policy. He contended as India was endowed with vast reserves of coal and limited reserves of petroleum, dieselization would mean import of crude oil when the demand would outstrip the supply and that too at the cost of huge drainage of foreign exchange.

The disposal of slack coal was another problem to the industry. This was due to greater mechanization yielding greater amount of fines, low off-take of the slack and

greater utilization of washery by-products for power generation. Considering that delivered cost of coal accounted for the major share in power generation costs, he favoured erection of power stations in and around the coal belt for utilization of slack which would rehabilitate to some extent this problem-ridden industry. He also suggested establishment of national grids and transmission networks for effective distribution of power. Installation of super thermal power stations might also mitigate the problem of slack coal utilization.

■ On the occasion of the Annual General Meeting of the Indian Mining Association, held at Calcutta on 14 May 1971, Shri J. F. N. Kalyanvala, Chairman, pointed to the rising trend in coal production. The despatch, however, showed a decreasing trend unmistakably due to short supply of wagons. As a result, many industries were starved of coal and were on the verge of closure. Low off-take of coal by steel plants and railways, according to Shri Kalyanvala, was another malady which plagued the industry. He suggested three remedial measures for the revival of the industry. They are: (1) reduction of cost, (2) subsidization, and (3) price rationalization by scientific methods.

Referring to the growing pattern of dependence on imported oil in place of coal, he said that it would be the task of the National Fuel Policy Committee to decide whether a country like India should spend much in the form of foreign exchange for its fuel bill while there are abundant resources of coal. On the other hand, if due importance is given to coal as the most important sources of energy in this country, coal producers would be the immediate beneficiaries and in the long run, the benefits would also accrue to the nation through self-sufficiency and fuller utilization of indigenous resources.

■ The Thirty-eighth Annual General Meeting of the Indian Colliery Owners' Association was held at Dhanbad on 29 March 1971 with Shri Rasiklal Worah in the Chair.

He stated that coal production diminished in 1970, perhaps for the first time in recent years, the overall raising declined by about three million tonnes and despatches by about six million tonnes. As a result the pit-head stock went high by about three million tonnes compared to the corresponding period of the previous year. Shri Worah blamed the Railways for such a state of affairs.

Stating that the greater portion of North Bihar was being starved of coal when Bihar itself was producing the major chunk of the material, he suggested that the Grand Chord be linked with the main line at some convenient point so that coal could be reached to those parts regularly.

Bemoaning the non-existence of a long term fuel policy for the country resulting in the present crisis of the coal industry, he welcomed the formation of the National Fuel Policy Committee and appreciated the decision of the government to set up coal-based public sector fertilizer plants and urged for setting up of more coal-based industries.

Referring to the vast reserves of non-coking coal and scarcity of prime coking coal, Shri Worah advocated the necessity of research for establishing their better utilization and economic mining. In this connection he commended the research work being conducted at CFRI and CMRS. Shri Worah felt that CFRI pilot plants on formed coke and low temperature carbonization should be developed on commercial scale.

Symposia/Seminar

"Potentialities of Use of Pine Oil as a Frother for Coal Flotation in India" was the title of the paper by G. G. Sarkar & B. B. Konar, CFRI, in a Seminar on the Role of Pine Resin in the Economic and Industrial Development of India held in New Delhi on 13 and 14 April 1971, under the auspices of SYMPINE — a body sponsored by the producers and processors of rosin and turpentine. 60 papers were presented and dscussed in the Seminar. Shri Sarkar, Assistant Director, CFRI, presented his paper and Dr D. P. Bhattacharjee, Scientist, attended the Seminar. A brief account of the paper appears in the 'Spotlight' section of this issue.

Coal Research Programme of the US Bureau of Mines

The present coal research programme of the Bureau can be listed in the following priority categories: projects involving the abatement of atmospheric pollution; investigations on converting coal to synthetic gaseous and liquid fuels; the use of coal to generate electricity; and finally, a wide variety of studies concerned with the non-energy uses of coal.

Air Pollution

Oxides of sulphur are found to be the most objectionable air pollutant. The problem is planned to be tackled in two ways. One is based on the absorbtion of these gases from let-off gases and the other is removal of pyrite from coal. The Bureau intends to use three dry methods for this purpose. Those are centrifugal, electrostatic and magnetic.

Absorbents like limestone, red mud, metallic oxides, shales, phosphate rock, alkalized alumina and pyrite are being tried for the removal of sulphur oxide pollutants from stack gases. Oxides of nitrogen are being decomposed catalytically. Success has been achieved in absorbing the oxides as nitrates on a nickel-oxide catalyst which can be reactivated by hot water washing. However, a more satisfactory solution to the nitrogen-oxide problem would be the development of a catalyst that would decompose the oxides into nitrogen and oxygen.

Coal Conversion

Foreseeing shortage of oil and gas, the Bureau lays stress on the conversion of coal, tar-sand and oil-shales into synthetic liquid and gaseous fuels. To provide for really significant decreases in the cost of converting coal to oil, two novel processes invented at the Bureau are being actively tested. In one, an alkyl group, such as methyl or butyl is added to coal by treatment with an alkali metal such as potassium, followed by reaction with an alkylating agent. The remarkable feature is that by the addition of relatively small amounts of alkyl agents, the coal is transformed into a new substance which is almost completely soluble in organic agents such as benzene. This, then, permits it to be handled as a liquid for removal of ash and to be converted further in conventional petroleum refining steps.

A second novel process concerns the conversion of coal to a benzene soluble product by hydrogenation using 'atomic' or 'nascent' hydrogen formed by contacting the coal with carbon monoxide and water under pressure. It is noted that under this set of conditions coal conversion

occurs more rapidly than with hydrogen gas. An interesting sidelight of the above exploratory work is the finding that garbage can be converted into a heavy oil. On dry basis, 40 per cent of the feed can be converted into oil.

Improved conversion of coal to oil is also being investigated by the search for new catalytic systems. It has been found possible to hydrogenate coal-oil slurries in a continuous operation over a cobalt-molybdena-alumina catalyst. Massive amounts of catalyst such as zinc halide are very effective in converting coal to gasoline.

Work with hydrogen donor organic compounds, such as tetralin and especially tars derived from coal is showing promise.

Coal Gasification

Research in the Bureau of Mines on coal gasification involves two processes, one using a combination of steam and oxygen and the second one employing hydrogen. Work is underway, also, on manufacture of hydrogen and producer gas at high pressures.

An integrated process for the manufacture of gas from coal consists of a fluid-bed gasification system using steam and oxygen at 40 atmospheres pressure and a temperature of about 1800°F. A mixture of methane, CO, CO_2 and H_2 is formed. This is followed by a partial gas shift ($CO+H_2O \rightarrow CO_2+H_2$) to bring the H_2/CO ratio to 3, then gas purification which is followed by methanation in a tube-wall reactor ($CO+3H_2 \rightarrow CH_4+H_2O$). Caking coals can be used directly. Gas from the producer is high in methane; it contains more than half the ultimate methane. As a consequence, a minimum amount of oxygen is used. The methanation is highly efficient and economical. Cost of gas manufacture, including plant amortization, is 43 cents per 1000 cu. ft. of gas, and the selling price is estimated to be 55 cents per 1000 cu. ft. This estimate is based on bituminous coal. Use of a less expensive fuel such as lignite would reduce the manufacturing cost by about six cents per 1000 cu. ft. of gas.

Combustion and Related Topics

The research efforts of the Bureau in the coal conversion to electricity programme can be grouped under three general categories. One deals with the problems involved in the conventional combustion of coal, another with studies into more efficient power systems like magnetohydrodynamics (MHD) and the third area relates to investigations into air pollution abatement by effective removal of gaseous and particulate pollutants found in stack gases following combustion of coal.

Virtually all processes for the conversion of coal to synthetic fuels produce concurrently varying quantities of char. As these chars often present combustion difficulties, sustenance of stable combustion is being tried by supplying heat from outside by burning natural gas or mixing high volatile coal with the char.

To assist in an effort towards a better understanding of the mechanism of the coal combustion reaction, coals and chars are being devolatilized by high current pulses. Determination of devolatilization rates of coals of different ranks and chars of various volatile contents as a function of decomposition temperature, together with continuing studies of the reaction rates of oxygen with carbon under controlled conditions of temperature and pressure are viewed as possible means of acquiring a better understanding of the combustion reaction itself.

Most of the MHD research conducted in the US has used alcohol, liquid hydrocarbons, and natural gas as fuel. The Bureau's work has been directed to the use of coal. The Bureau has been studying the high temperature combustion of coal in a furnace burning 125 lb per hour of coal at 4000°F with oxygen-enriched air seeded with potassium carbonate. There have been studies concerned with the contamination of the combustion plasma, the corrosive attack on boiler tube materials at several temperature levels, the distribution of seeding material in the slag and fly ash with economic recovery of the seed, the removal of sulphur oxides by the seed with subsequent regeneration of the spent seed and finally the problem of nitrogen oxide formation and its reduction.

For the MHD system fired with coal to be economically feasible, virtually complete seed recovery is required. Based upon studies conducted so far, the loss of seed with the slag and fly ash has exceeded the levels that can be tolerated. To overcome this difficulty, a coal combustor of special design is required wherein substantial amounts of ash are eliminated ahead of the generator itself. At the bench-scale level, complete capture of the sulphur oxide resulting from the combustion has been made by the seed material and complete recovery of the sulphur in the form of H_2S has been obtained by regenerating the spent seed with hydrogen and steam or by hydrogen and carbon dioxide mixtures. Air injection is found to reduce the levels of nitrogen oxides formed. The Bureau has built and is now testing a vortex MHD generator of novel design. The combustor and generator are single unit encompassed by a single solenoid magnet. This principle, if workable, will result in a compact design having economic advantages.

Another Bureau study involving the application of improved combustion practices has been the design, construction and start-up of a vortex incinerator for burning of municipal waste. This experimental unit with a design capacity of 100 lb per hour of refuse has a continuous feeding system and provisions for providing combustion air tangentially above the feed as well as auxiliary air below the feed. It is believed that these design features and the reduction in heat losses by heat exchange to the incoming air, use of refractory insulation and the low surface-to-volume ratio of the incinerator will result in more efficient combustion.

The Bureau is investigating both the removal of particulate matter by electrostatic precipitation and the removal of gaseous pollutants from flue gas by absorbtion. Effectiveness of collection in electrostatic precipitator is affected by the sulphur content of the fuel and many plants are forced to enlarge precipitator capacity with an increase in sulphur content of the fuel. For most effective separation, the electrical resistivity of the solids must fall within well-defined limits. The preferred range of electrical resistivity is between 10^3 and 2×10^{10} ohm cm for the removal of entrained solids from oxidizing gases by electrostatic precipitators.

Engineering data are being obtained to assess the commercial potential of fluidized bed combustion of coal. Because the temperature of combustion is lower than conventional firing techniques and the system lends itself to the injection of sorbents for SO_2 absorbtion, fluidized bed combustion offers reduced pollution potential. Studies are in progress to determine the amenability of various coals to combustion in a

fluidized bed. Other investigations are planned to evaluate the performance of boiler tubes and obtain information on heat transfer during the firing cycle. The use of low frequency and vacuum far infrared spectrometry is being used to determine the amounts of individual minerals and inorganics in various coals burnt for electric power generation and in those coals used in the Bureau's experimental fluidized bed combustion equipment. A problem related to combustion of coal in pulverized fuel power plants is the frequent deposit formation in boiler tubes by alkalies, especially sodium. It is being tackled by treating coal with an aqueous solution of calcium salts.

Studies are being made to correlate electrical resistivity with chemical composition of the coal and the ash so that a simple chemical analysis may be used to predict problem coals. Electrostatic precipitator performance characteristics are being determined, also, in reducing gas mixtures at high temperatures and pressure.

Towards the utilization of fly ash, the Bureau has been able to use it for neutralizing the acidic conditions found in surface mine spoil banks and promote vegetable growth. Other study areas include the use of sintered fly ash to improve the physical condition of soils and the addition of fly ash to automobile tyres to provide superior traction and skid resistance.

Basic and Exploratory Research

Basic research programme is oriented to elucidate the structure of coal and coal-derived products, to determine the mineral constituents of coal which tend to interfere with its utilization and to improve or develop new analytical tools and techniques applicable to coal and its products.

A spectrometer employing a liquid helium magnet is being developed to determine the mode of occurrence of sulphur in coal. The use of a nuclear device has been developed as a continuous and automatic method for measuring moisture in coal and has been tested on a commercial plant scale. A nuclear device employing the rare man-made element, Californium 252, is being developed further to measure the sulphur content in a moving stream of coal.

Exploratory experiments have been carried out to test the capability of ultrasonics to solubilize coal and to bring about chemical reactions with high energy laser beams, electron discharge or electrochemical treatment.

Research is also being carried out on other areas of application of coal such as (i) coking of coal for use by the steel industry, (ii) production of chemicals from coal, (iii) application of coal in agriculture, and (iv) exploratory research on coal.

Improvement in coke production, besides effecting modifications in the existing processes, is being tried by the use of antifissurants in coking blends. Entrained carbonization is also under study.

New possibilities of obtaining significant chemicals from coal are being investigated; an example is the conversion of coal to phthalic acid using novel catalytic reactions. Previous investigations resulted in a carbon black of interest to industry for use in reinforcing rubber.

Coal humates such as leonardite, a naturally occurring oxidized lignite, have shown some promise in increasing crop yields of potatoes and soyabeans. This work is being carried on in cooperation with North Dakota State University. Exploratory studies are under way of testing high energy treatment of coal. This includes exposure of coal to the electrical discharge, corona discharge, and laser rays. Active radicals are generated which are capable of forming chemicals of interest, especially acetylene.

For effective separation of fine pyrite particles from fine coal in froth flotation unit, zeta potential determinations are being made on suspended coal and pyrites particles alone and in the presence of reagents which show that the multivalent metal salts, particularly ferric and chromium salt, effectively depress pyrites.

These zeta potential studies have led to the development of an electrophoresis column wherein electrophoretic mobilities of coal and pyrite together with their differences in specific gravity will permit separation of the two. [Based on *US Bureau of Mines Bulletin*, 1970].

Polluted Water Treatment with Fly Ash

University of Notre Dame, in a paper presented to the Second Ash Utilization Symposium, reports that the treatment and renovation of various polluted waters offer a relatively new area for innovative utilization of fly ash. Certain properties and characteristics of fly ash made this material quite amenable for use in the treatment of such polluted waters as eutrophic lakes, waste water treatment plant sludge and acid mine drainage. Notable among these features of fly ash are adsorptive properties which provide effective removal of soluble organic matter from polluted water, water extracts of lime and gypsum which effectively precipitate inorganic phosphorus and neutralize acid conditions in polluted waters and the particulate characteristic which allows this material to be used as a conditioner of waste water sludges for excellent dewatering by vacuum filtration.

The degree of acid neutralization with fly ash is time dependent as longer contact times result in more lime release from the fly ash particles and thus a higher degree of acid treatment. It appears that the total acidity of an acid mine waste is the quality parameter which dictates the amount of fly ash needed to neutralize the waste. [*Coal Age*, May 1970, 87].

Lead-free Petroleum Fuel for Automobiles

Both Shell and British Petroleum have announced that they will provide lead-free petrol suitable for vehicles of a lower compression ratio than existing models but at increased cost.

With increased political interest in the US in engine exhaust pollution, the severity of legislation against the emission of carbon monoxide and hydrocarbons is to become greater. Concern has been expressed in some countries in respect of the use of lead containing additives in petrol and the possibility that these materials constitute a health risk. Though both Shell and BP maintain that the present levels of lead in petrol constitute no danger to health, they admit that in the absence of lead it becomes easier for engine manufacturers to make design changes which will result in reduced emissions of carbon monoxide, hydrocarbons and nitrogen oxides which are the principal exhaust pollutants. In these circumstances, the US motor manufacturers have concluded that to meet future legislation, they will need to use catalytic after-burners, which in turn demands that US oil industry must supply lead-free petrols so that the after-burners may operate satisfactorily.

Following the decision already announced in Detroit to produce vehicles of lower compression ratio and suitable to the use of 91 octane gasoline, Shell Oil Co. in the US have announced their plans to produce a non-leaded gasoline.

With normal compression ratios (9:1 to 10:1), the engine revisions required to meet the NO_x emission levels severely restrict engine performance, causing increases in fuel consumption as high as 40 per cent. It is calculated that if efficiency losses of this magnitude are experienced, it is reasonable to use lower compression ratios to reduce emissions (through reduced peak temperatures and pressures, and improved surface-to-volume ratio). If compression ratios were reduced, the octane requirement would be significantly reduced also, the resultant low octane (about 91) fuel could be fairly easily made without the addition of lead. With non-leaded fuel it then becomes practical to use catalytic devices for exhaust treatment. In addition, reductions in deposits in exhaust gas recirculation devices are also possible.

It has, however, been realized that though the reduction in compression ratio is a viable solution with large American automobiles, with the smaller European and Japanese vehicles, this is hardly likely. A reduction in compression ratio to the same level as contemplated for US vehicles could result in a loss in power and economy to as much as 10 per cent. Researches are under way to overcome this deficiency. [*Science Journal*, May 1970, 23].

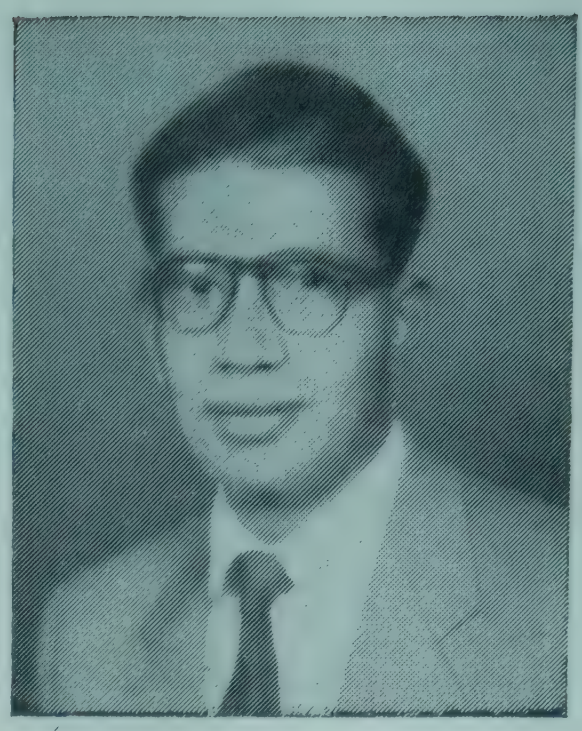
STAFF MATTER

Promotions

We congratulate the following on their promotions:

(i) *Mr V. A. Krishna Murthy* — Mr V. A. Krishna Murthy, Scientist C, was promoted to Scientist E (31 May 1971) after thirteen years of creditable service to the Institute in various capacities.

After his degree in Science from Mysore University in 1951, Mr Krishna Murthy took D.I.I.Sc (Chem. Engng) and A.I.I.Sc (for his thesis on Technical Gas Reactions) from Indian Institute of Sciences, Bangalore. Subsequently, with a Government of India senior research fellowship (1956-58), he worked on "production of phosphatic fertilizers by hydrochloric acid treatment of phosphatic



Mr V. A. Krishna Murthy

nodules" and "high pressure catalytic amination and ammonolysis reactions for the production of amines", at Bangalore. Mr Krishna Murthy joined the CFRI in 1958 as Junior Scientific Officer. He was successively promoted to Scientist B in 1960, Scientist C in 1963 and now to Scientist E.

At CFRI he was associated with the development of various processes and designing of pilot plants. To mention a few, Mr Krishna Murthy worked on the synthesis of hydrocarbons, gas purification and production of chemicals from synthesis gas by Fischer-Tropsch process. He then took up the problems of catalytic hydrogenation of carbon monoxide to hydrocarbons & chemicals, and catalytic oxidation of naphthalene to phthalic anhydride on a pilot plant scale. Mr Murthy is now engaged in the planning and design of a coal hydrogenation pilot plan, hydrocracking of petroleum residues for the production of middle distillates, hydrofining of benzoles and scaling up problems in the field of synthesis of chemicals, waxes and fatty acids, etc.

In 1965-66, Mr Krishna Murthy was deputed on a Unesco fellowship to West Germany, where he worked with Prof. Koelbel in the field of chemical reaction engineering with particular reference to hydrogenation reactions in slurry phase reactors.

Mr Krishna Murthy is an Associate Member of the Institution of Chemical Engineers.

To date, he has published eleven research and review papers.

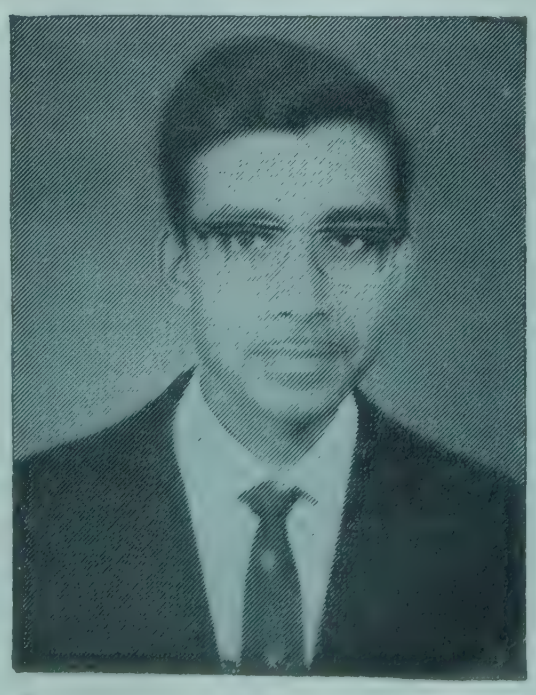
(ii) *Dr M. Chakraborty* — Dr M. Chakraborty was promoted to Scientist E on 31 May 1971. At CFRI, Dr Chakraborty has been associated with the pilot plant developments of processes for the production of chemicals from coal including the preparation of catalysts required. Besides other assignments, he is at present engaged in the studies relating to the production of phthalic anhydride, anthraquinone, benzaldehyde, etc., all from coal tar. [For his accomplishments and biography please also see *FRI News*, September 1969.]

(iii) Sarvasree S. K. Basu, P. K. Dasgupta and S. K. Chanda to JTA.

(iv) Shri S. R. Sharma to TA (photography).

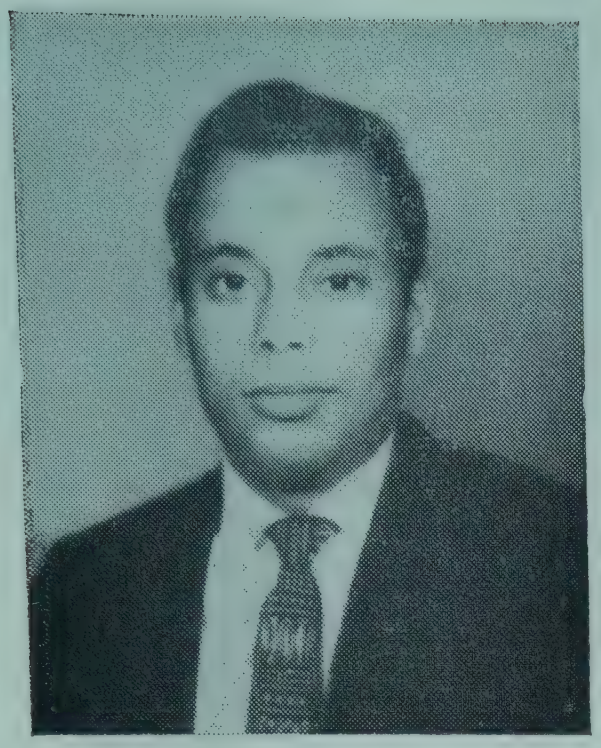
Deputations

Sarvasree G. Sitaram Murthy, Scientists, S. K. Chatterjee and Subodh K. Ray, both Scientists 'A', were deputed to Australia on 28 March 1971 for a 9-month postgraduate training in 'Research Techniques in Chemistry' under Colombo Plan.



Dr M. Chakraborty

Shi G. S. Murthy



Shri S. K. Chatterjee

Shri S. K. Ray

■ Shri N. C. Sinha, Scientist C, resumed duties after the expiry of the four-month deputation in UK under the Technical Assistance Training Scheme.

Shri Sinha was attached to the Physics Department of British Coal Utilization Research Association's Industrial Laboratories at Leatherhead, UK, and studied 'Grindability and Abrasiveness of Coal'. During the period, Shri Sinha completed two specific projects: (i) a study of the effect of upper grinding ring of hardgrove machine on the grindability of coal; and (ii) a study of abrasiveness of coal and associated minerals in relation to pulverizer wear.

Shri Sinha visited and studied the work of many other important laboratories such as: (i) Mineral Processing Division of Warren Spring Laboratory, Stevenage, Herts; (ii) Scientific Service Department (comminution group), NE Region, CEGB, Leeds; (iii) Process and Engineering Division of M/s International Combustion Limited, Derby. He also visited CERCHAR Laboratories, Creill, Paris.

Nomination

Dr A. Lahiri, Director, CFRI, has been nominated as a member of the 'Working Group' set up by the Ministry of Steel & Mines for reviewing, coordinating and ensuring speedy completion of coking coal testing programme for the new steel plants to be set up at Visakhapatnam and Hospet. Mr A. K. Moitra, Assistant Director, has been accepted as alternate member.

Resignations

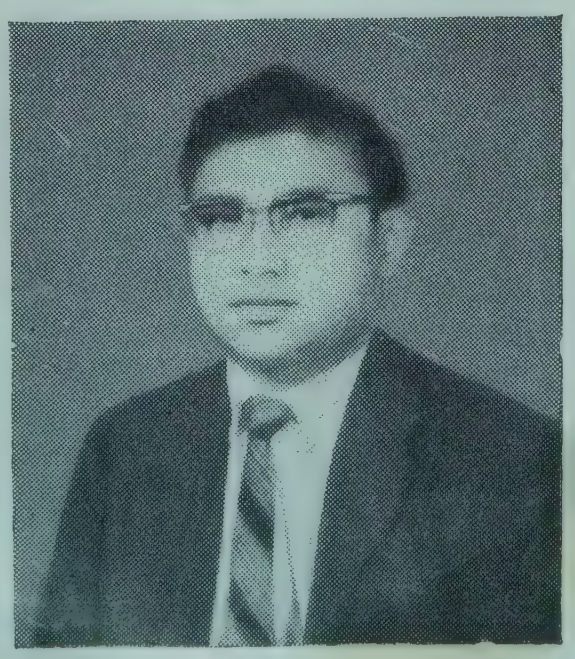
We express our best wishes to the following who have relinquished their posts from CFRI for other occupations (i) Dr A. K. Choudhury, Scientist (w.e.f. 3 June 1971), and (ii) Shri Sibapada Ghosh, JSA (w.e.f. 17 April 1971).

Appointments

We welcome the following to our staff:

(1) *Dr S. C. Chakravartty* — Dr S. C. Chakravartty, who joined CFRI on 1 June 1971 as Scientist C, had a brilliant academic career throughout.

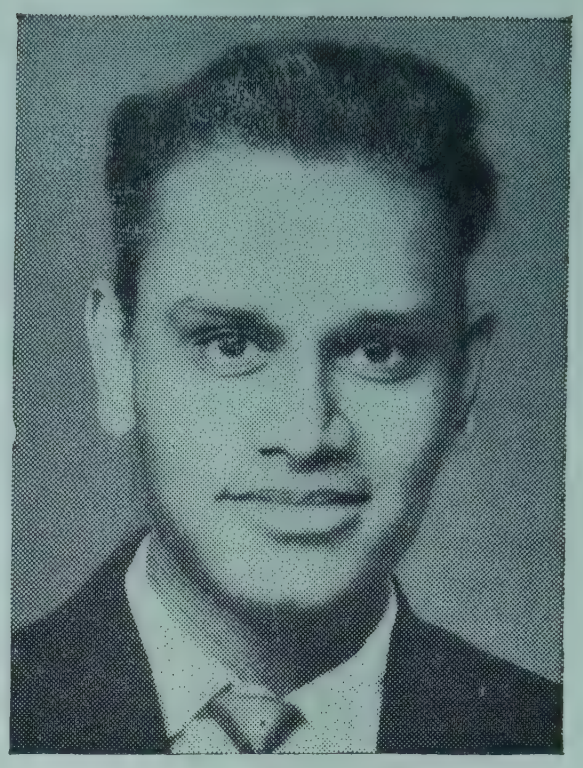
Dr Chakravartty got a first class Honours degree in Physics with Distinction from Ranchi College in 1959. He was awarded M.Sc. (1st in 1st Class) in Physics in 1961 by Ranchi University. Dr Chakravartty was the recipient of Ranchi College Medal and Ranchi University Gold Medal for standing first in B.Sc. (Hons) and M.Sc. examinations respectively.



Dr S. C. Chakravartty

Dr Chakravartty worked as a Lecturer in Ranchi University for the period 1961-63. Later he proceeded to Canada where he obtained M.Sc. in 1965 from Windsor University, Canada, for his thesis on 'Solid State Physics'. In 1970, he secured his Ph.D. degree in Physics from Ottawa University, Canada, for his thesis on 'High Energy Physics'. In Canada, he studied various fields of physics, e.g. solid state physics, particularly EPR, High Energy Physics and Plasma Physics.

Dr Chakravartty has to his credit five research papers. He is a member of a Canadian Association for the Physicists.



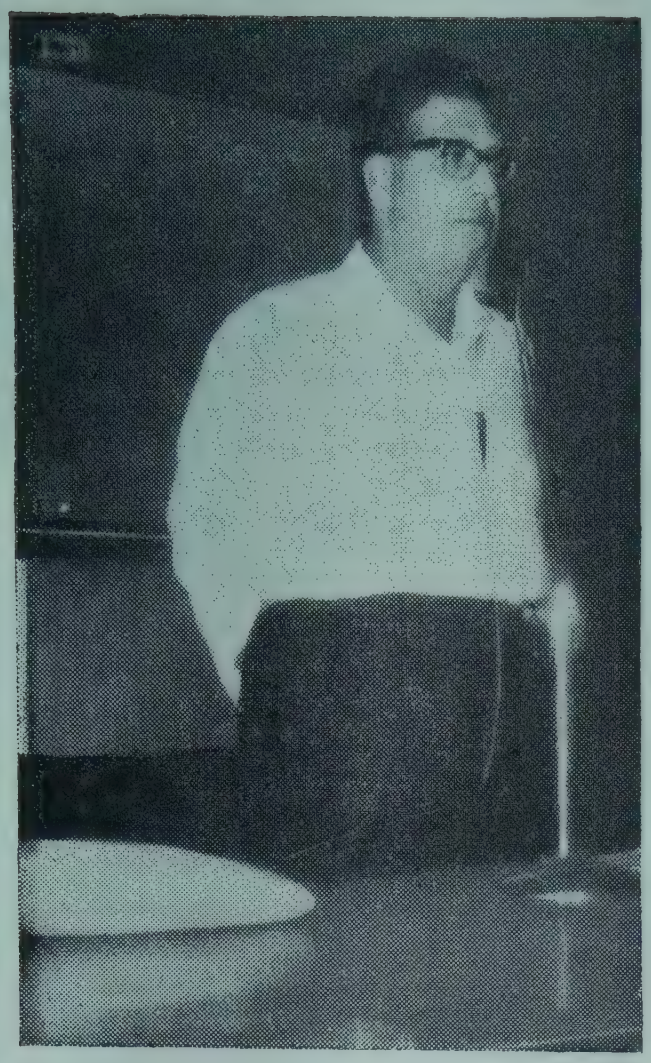
Dr D. G. Takte

(ii) *Dr D. G. Takte* — Dr D. G. Takte joined CFRI on 24 June 1971 as Scientist C. He worked earlier in the Regional Research Laboratory, Hyderabad, from 1962 to 1966 before going abroad.

Dr Takte obtained B.Sc. (Hons) degree in first class from Poona University in 1959 and then passed M.Sc. in Physical Chemistry with first class in 1962 from the same University.

He joined the RRL, Hyderabad and worked in areas like Solid State Chemistry, Surface Chemistry, Catalysis, etc.

Dr Takte was selected in 1966 by the Commonwealth Scholarship Commission in United Kingdom where he earned his Ph.D. degree from the University of Belfast, U.K., for his work on 'Heterogeneous Catalysis'. He was elected as Associate Member of



PROF. ENDRE VAMOS

the Royal Institute of Chemistry, London.

Dr Takte was then invited by the Department of Physical Chemistry, Technological University of Delft, The Netherlands, where he spent about a year continuing his research interests in the field of heterogeneous catalysis.

Before returning to India, Dr Takte visited some of the leading catalytic research centres of Europe.

Visitors

Prof. Endre Vamos, Head of the Division for Application Research Institute, Budapest (Hungary), spent four days at the CFRI in the course of his visit to India under the Indo-Hungarian Scientists' Exchange Programme.

As an expert in chemical reactors, especially in the field of petroleum and lubricants technology, and intimately connected with application of research results in industry in a big country, Prof. Vamos was highly impressed by the various industry-oriented research projects of the Institute and expressed that for a developing country like India, such a programme of work was of utmost importance. He evinced particular interest in the production of synthetic oil and chemicals from Assam coal by hydrogenation. At CFRI he delivered a lecture on "Development of lubricants and lubricating oil in Hungary" which appears as an article elsewhere in this issue.

Born in Budapest in 1921, Prof. Vamos obtained the degree of Candidate of Chemical Sciences (equivalent to Master's Degree) from the Hungarian Academy of Sciences in 1958 and the Doctor of Engineering from University of Chemical Engineering, Veszprem, Hungary, in 1966.

Serving different organizations in various capacities, Prof. Vamos has studied: (a) development problem of lubricating greases, (b) synthetic tanning agents, (c) paraffin wax oxidation, (d) extraction of paraffin base lubricating oils, (e) solvent dewaxing of distillate and residual oils, (f) refining of naphthas and white oils- (g) development of synthetic deter, gents, (h) production of yeast from hydrocarbons, (i) fuel oil additives, (j) temporary corrosion prevention, (k) microbiological corrosion, (l) viscometry, (m) rheology, (n) electron microscopy, and (o) chromatography.

Prof. Vamos has 270 scientific and technical papers, 30 patents and 19 books to his credit.

CFRI ABSTRACTS

THE PROBLEMS OF SUPPLY OF QUALITY COKE FOR INDUSTRIES, by A. Lahiri, & K. Raja [*J. Instn Engrs (India)*, **52** (1971), 2, Part CH1, 3-8].

The demand of hard coke by the end of Fourth Plan for various industries both ferrous and non-ferrous has been projected. The availability and requirement of coke for different industries, viz. iron and steel, foundries and allied industries, ferro-alloys and calcium carbide, non-ferrous industries, etc., are discussed. The standard specifications of coke formulated for the different purposes have also been indicated.

BENEFICIATION OF COKING COALS IN INDIA, by G. G. Sarkar & A. K. Chakravarti [Presented to *the Symposium on The Coal Mining Industry*, No. III, CFRI Dhanbad, 14-15 February 1970, organized by MGMI & JWC].

The supply of metallurgical coal of required quantity and specifications to our expanded iron & steel industry has been made possible through adoption of coal beneficiation techniques and timely installation of a number of coal washeries. But for these washeries, the country might have been faced today with the problem of importing large amounts of coking coal. The beneficiation techniques, which are employed in the existing washeries in India are varied in nature and are meant to suit the cleaning and size characteristics of the coals as well as specific requirements. The variation in the capacity of the individual washeries, the diversity in their washing schemes and in some cases, dissimilarity in the basic designs of the washing baths and their auxiliary units have resulted in multiplying components and spares in the washery equipment inventory.

From experiences gained so far on the operation and maintenance of coal washeries in India and a study of their overall performance, it is revealed that almost one-third of the country's available washing capacity remains unutilized owing principally to the non-availability of essential spares and replacements. The supply of feed coal to the washeries is also showing a tendency to deteriorate in quality. All future washeries will have to draw their supplies from coal seams, whose beneficiation potential will be significantly different from those being mined now in this country. Most of these coals will need finer crushing before the intergrown dirt can be effectively released from them.

Based on present-day operating experiences and the likely trends in the supplies of raw coal to future washeries, a simple and compact washing circuit for coking coals is proposed and suggestions for rationalizing the capacity and design of washery components are put forward. Standardization of design and capacity of the washery components can go a long way in helping indigenous manufacture of complete plants and equipment and in solving the problem of spares.

In the coming years, the attendant problems of upgrading inferior coals in finely crushed sizes will have to be tackled efficiently and economically. An integrated process for simultaneous upgrading and dewatering of coal, developed by CFRI and patented under the title 'Oleoflotation' holds much promise for effective dewatering of small and fine sized coals including slurry.

The scope and need for further research on coal preparation problems including design of standard blending equipment, storage, dewatering and/or loading bunkers and development of improved process for fine coal or slurry treatment are briefly referred to in this paper. Effective solution of these problems can be found only through the collaborative efforts of research and design organizations as well as manufacturing firms dealing with the same or allied units/equipment.

GROUPWISE CLASSIFICATION OF THE BARAKAR MEASURE SEAMS OF THE JHARIA COALFIELD, by B. Banerjee & M. M. Alam [Presented to *the Symposium on The Coal Mining Industry*: III, CFRI, Dhanbad, 14-15 February 1970, organized by MGMI & JWC].

The paper presents a detailed study on the geochemical characteristics as well as the carbonization and washability potentialities of the Barakar Measure seams of the Jharia coalfield. Besides, the megascopic characteristics, coal to shale ratio, quality and many other important properties of the seams are presented. The study shows that the seams occurring in the Barakar Measures of Jharia coalfield have a remarkable sequence of properties from the top to the bottom and that depending on the spectrum of such properties, both scientific and technological, these coals may well be classified into four horizons (each horizon containing a group of seams) having distinctive utilization pattern. Such groupwise classification of the eighteen major seams of the Jharia coalfield has been highlighted in terms of their atomic H/C ratios (i.e. rank) and their coking potentialities. All other properties fall in line in such grouping.

Thus the groupwise classification not only gives an instantaneous picture of the types of coal available in the Barakar coal Measures of Jharia coalfield but also provides with a perspective view of their utilization pattern.

BLENDING AND STOCKING OF COALS, by G. G. Sarkar, A. K. Chakravarti & S. K. Sen [*J. Min. Met. F.*, special volume on Symposium on Bulk Handling of Raw Materials, 1969, 116].

The central washeries in India pose the most difficult problem in blending and stocking of raw feed to the plants. Some of the central washeries receive supplies of raw coal from as many as 25-30 different collieries, each mining on the average two to three different seams. The raw coal ash, the size consist and the cleaning characteristics of one are very often different from the other. Thus to avoid the ill effects of such variations in size and quality on the smooth and efficient operation of the washery, it becomes essential to keep proper blending-cum-storage facilities for the incoming raw feed to the washery.

From a survey of the blending provisions made in different washeries in India, three distinct systems are observed to be in

use. These are (i) pocker blending from individual hoppers, bins or silos; (ii) trough blending from slit bunkers; and (iii) bed-blending by Robins-Messiter System. In addition to these three conventional systems, there are a few more like cell bunker or organ pipe bunker which have been tried in foreign countries. But comparatively these are of minor significance. Even in bed blending systems, several types of reclaimer, e.g. harrow type (Robins-Messiter System) and wheel or paddle type (Hewitt-Robins System) have been used.

Although the comparative performance of the different blending systems are yet to be evaluated, the general opinion is in favour of bed-blending system employing harrow-type reclaimer. It is high time that the results of the different blendig systems incorporated in the central washeries under operation in India should now be made available and a standard system be adopted in all future washeries, where blending of raw feed is envisaged. But before standardization of such a system, considerations have to be given to the day-to-day operating and maintenance problems, availability of equipment and spares from indigenous sources and also the economics as judged in the light of comparative performance of the different systems. The throughput capacity of the plant incorporating the blending system may play an important role in taking a final decision in the matter.

CENTRAL BLENDING SYSTEM, by A. K. Moitra & S. K. Sen. [*J. Min. Met. F.*, special volume on Symposium on Bulk Handling of Raw Materials, 1969, 125].

In India, high grade but relatively meagre resouces of raw materials will have to be conserved and as such blending materials of high grade for blending with relatively lower grade or category without adversely affecting the quality of the marketable product is absolutely essential. In the context of the large-scale steel production in India there will be a rise in demand of coal for coking at the various steel plants and a daily handling of about 6000-10,000 tonnes of coal of similar type but of varying qualities from different sources at the central washeries or of different types from many sources has become indispensable. This calls for an effective blending system.

The most highly developed method of blending large volumes of bulk materials with the desired degree of uniformity is the bed-blending system. In coal industry such a blending system has to be installed in between the arrangements for receiving incoming constituent coals and the units for selective crushing and mixing. The blending system consists of 4 distinct stages in sequence providing for the operations detailed hereunder: (1) Unloading of each individual type of coals from different sources and storing them separately in adequate quantity in buffer stocks. The arrangement required will be determined by heterogeneity of coals received. (2) Spreading the material at a uniform rate, back and forth over a long area, thus gradually building up a pile composed of several layers. (3) Reclaiming the layered pile or bed after it has been completed, by consecutively removing small cross-sectional increments. (4) Arrangements for further crushing and/or pulverizing the blended coal and delivery of the finely crushed coal to the service bunker of the coke oven after imparting requisite treatment in a unit for selective crushing, mixing and/or oil blending.

The paper deals in general with the various blending systems particularly central system for bulk treatment of categories of coals for coking under Indian condition and indicates the advantages and disadvantages of each system.

COAL PREPARATION AND HANDLING PRACTICE FOR MODERN THERMAL POWER STATIONS, by S. K. Majumdar & S. Bagchi. [*J. Min. Met. F.*, special volume on 'Symposium on Bulk Handling of Raw Materials', 1969, 134].

Demand for power in India is increasing at a fast rate. A major portion is being generated in coal based thermal power stations. They may expand and many more new plants are expected to be installed to cope with the future demand.

The contribution of coal towards the cost of generation of power exceeds 80 per cent. Hence all attempts are being made to utilize them most efficiently and also to minimize all possible expenses on them.

The need for utilization of inferior grade coals, which has considerable reserves throughout India calls for rationalization of zonal production and distribution which will obviously eliminate cross-movements and save expenses on transports (capital and recurring).

Bulk of coal required for any modern power station requires extensive arrangement for transportation, handling, preparation, storage and some amount of blending.

Utilization of inferior grade coal and washery byproducts in large power stations requires expensive preparation and conveying systems. Further they require collection, handling and transportation of large tonnages of ash produced every day whose disposal may create serious problems in the long run.

PRESSURE GASIFICATION OF SOME NON-COKING COALS, by D. K. Biswas, R. R. Biswas, J. R. Mitra, S. K. Mitra, R. N. Bhattacharjee, M. N. Juneja, A. Mazumdar & M. M. Sen. [*Indian J. Technol.*, **9** (1971), 63-69].

The fixed bed pressure gasification pilot plant installed and commissioned for experimenting with Indian coals is described. The results of gasification trials performed with typical non-coking coals of Talcher field (Orissa), Raniganj field (West Bengal), Singareni field (AP) and Sohagpur field (MP) are presented and discussed. The performance of the gasifier, judged from the value of gas yield and quality, percentage carbon gasified and cold gas efficiency, has been examined in relation to the plant pressure employed. Well-defined relationships have been found to hold good in most of the cases examined. The requirements of the principal raw materials, namely coal, steam and oxygen for producig 1000 Nm^3 of raw and CO_2-scrubbed gas have been worked out. Data concerning the yield of byproduct tar for the coals tested are given and detailed analysis of a tar sample is presented to illustrate the quality of byproduct tar obtainable. The tests conducted bear a special significance in the context of the country's expanding demand for synthetic fertilizers and chemicals, and oils and the need for developing the town gas industry.

Hard Coke Industry in India — *Contd from p. 37*

The CFRI has also contributed in recent years in appreciable measure to the development of the beehive coke industry. In advanced countries beehive coke ovens are generally standby carbonization device of low capital cost to take up excess demand that might arise during periods of extraordinary industrial activity caused by short boom times or by war. This is not so in India. Being of less capital intensive nature perhaps and due to ease of operation, a number of beehive ovens are functioning in the country especially to meet the coke demands of the foundry industry. Accounts of CFRI services to this sector have been published in this journal periodically. Much contribution has already been made to increase the operating efficiency, economy, use of blends (in place of only prime coking coal), etc. It may be expected that the experience being gained by the Institute's research personnel in this field in association with the industry will lead to design of more efficient ovens and considerably improve the operating practice.

An appraisal of the coals of Pathakhera area, Pench-Kanhan-Tawa Valley coalfield based on the assessment of coal quality from the borehole coal cores by the Coal Survey Laboratory of CFRI at Nagpur has helped National Coal Development Corporation to open the Pathakhera colliery to supply fuel to the Satpura Thermal Power Station of the M.P. Electricity Board. The nature and properties of the coals have been presented in another article published in this issue of the *FRI News*.

The third article covers a lecture on " Trends in the Development of Lubricating Oils ", delivered by Dr E. Vamos, Head, Applications Research & Development Division, High Pressure Research Institute, Budapest, while he was on a visit to the Institute recently.

Chief Editor: S. RANGA RAJA RAO

Editor: SAMIR SEN *Assistant Editor*: R. S. SAHA

Yearly Subscription: Rs. 4 This Copy Re. 1

Available from

CENTRAL FUEL RESEARCH INSTITUTE, P.O. F.R.I., DT. DHANBAD, BIHAR, INDIA

PHONE: JHARIA 6205. GRAMS: RESEARCH, JEALGORA

PRINTED AT THE CATHOLIC PRESS, RANCHI

Registered with the Registrar of Newspapers for India Under No.

R.N. 3872/57

Vol. 21
No. 4

FERIS

DECEMBER
1971

89

CFRI LIBRARY
MYSORE-6
3 NOV 1972

IN THIS ISSUE

EDITORIAL
(Coal-based Power Stations) -- 73

COAL-BASED THERMAL POWER STATIONS—A SURVEY AND PRELIMINARY STUDIES ON THEIR PROBLEMS IN INDIA --- 74
M. Banerjee, R. R. Biswas, J. R. Mitra & B. Acherjee

ABRASIVENESS OF COAL AND ASSOCIATED MINERALS IN RELATION TO PULVERIZER WEAR ---- 85
N. C. Sinha

AN APPRAISAL ON THE QUALITY OF COALS OF KANHAN VALLEY COALFIELD ---------- 96
S. Sen, S. M. Singh, B. A. Samannu, B. D. Majumdar, R. N. Kudwalli & K. Y. Shrikhande

SPOTLIGHT ON SCIENTIFIC ACTIVITIES

FEASIBILITY STUDY ON THE UTILIZATION OF KUTKONA COALS OF M.P. -------- 104

PRODUCTION OF ANTHRAQUINONE FROM ANTHRACENE - 105

RAPID NMR METHOD OF ESTIMATION OF WATER ----- 105

PHASE BOUNDARY DETERMINATION ------- ----- 106

NOTES & NEWS

COMMITTEE AND MEETING -- 107

FLY ASH FOR REMOTE FILLING OF MINE VOIDS -------- 109

FLUID BED REACTOR DEFEATS NAPHTHA SHORTAGE ----- 109

SPHERICAL AGGLOMERATES MAKE GOOD COKE ------ 109

STAFF MATTER ------ 110

OBITUARY
(Shri K. P. Banerjee) ---- 111

CFRI ABSTRACTS ------ 112

Coal-based Power Stations

THERMAL power, which is by and large based on coal, accounts at present for about 55 per cent of electricity generated in the country. The present annual consumption of coal for power generation is 17 m.t. and is likely to be 57 m.t. in 1978-79, increasing to about 100 m.t. by 2000 A.D. to meet only 50 per cent of the total estimated demand of 324 billion kWh by that time. The rest of the electricity generation will perhaps be based on hydro and nuclear.

While the country's progress in power generation capacity has grown from 2·3 million kW in 1050-51 to 17 million kW over a period of 20 years, severe shortages of power have been experienced recently in several States. Indications are that the gap between the demand and installed capacity is also likely to grow continually. What is, however, perhaps a matter of great concern is the poor operational efficiency of the electricity plants, especially in the context of shortages.

The thermal stations in the country, it is stated, generated on an average about 3500 kWh of energy per annum for every kW of installed generating capacity, as against 4700 kWh in the USA and 5600 kWh in Japan. Although the above is average for the country, many thermal power plants have even lower efficiency than conceived under normal operating conditions. The comparatively poor performance of the country's generating stations and the high loss in transmission and distribution (estimated as 20 per cent) had necessitated the provision of generating capacity with a wide and uneconomic margin. For a peak load demand of 14 million kW at the end of the Fourth Plan, the generating capacity required will be 20 million kW. This low level of efficiency will apparently continue to figure in the Fifth Plan when it is anticipated for a peak load of 29 million kW, the generating capacity to be installed is proposed as 40 million kW!

It is in this context that the two articles in this issue of the *News* are topical as they draw attention to the problems in the coal-based thermal power stations and the trend in their solutions. The CFRI in recent years has been associated with the trouble shooting in a number of power stations and in the course of their work, critical survey of some of the problems has been made by its engineers.

(*Continued on page* 94)

COAL-BASED THERMAL POWER STATIONS— A SURVEY AND PRELIMINARY STUDIES ON THEIR PROBLEMS IN INDIA

LARGE expansion in electric power generation capacity has taken place in the country since independence. In spite of greater contribution by hydel power compared to the past and the advent of atomic energy, coal-based power has contributed the maximum in this progress and will continue to hold its prime role undiminished at least up to the turn of the century. The consumption of coal for power generation by that time is expected to reach 100 m. tons annually to meet 50 per cent of the total demand of 324·3 billion kWh (Fig. 1)[1]. The post-independence expansion of thermal power generation in India is marked by three distinctive features, viz. (i) an urge for planned and rational utilization of the fuel resources of the country for power generation as a consequence of which it has been made obligatory for all power stations to use byproduct fuels of coal preparation plants wherever available in the Bengal-Bihar coalfields and to use slack and low grade coals in the outlying fields; (ii) almost exclusive installation of large PF fired boilers incorporated with boiler design to permit utilization of low grade fuels with high efficiency and to gain techno-economic advantages of using large sized units with high steam temperature and pressure; (iii) a clear emphasis for locating the power plants in the vicinity of coal preparation plants and pitheads (Fig. 2) to minimize transporting difficulties and to keep freight charge for fuel transportation at its lowest. High voltage grids for economic transportation of energy to consumption centres have been developed and interconnection between hydel and thermal power grids established for appropriate sharing of peak load and base load between the two.

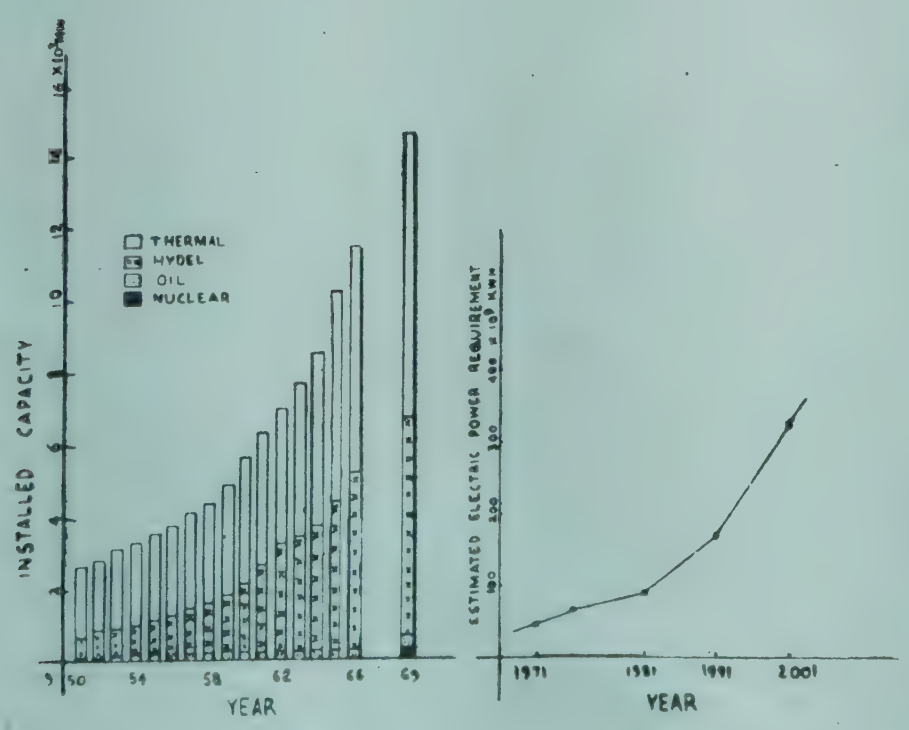


FIG. 1 — CONSUMPTION OF COAL FOR POWER GENERATION

The main objective has been to ensure sufficient supply of power at a cheap rate at scheduled hours, and consequently high boiler availability and efficiency. Unfortunately, these could not be maintained at desired levels in all instances. Fig. 3[2] shows the installed power generation capacity and power actually generated during the period 1951-66. Inescapable loss in output arising out of normal plant overhauling and fluctuations in demand fail to justify the wideness of the gap. The most serious factor responsible for the decreased output of power is obviously poor boiler availability. The PF firing, though efficient for burning of low grade coals and is very widely adopted, is yet beset with problems and the fuel quality decides to a large extent the nature and magnitude of these problems.

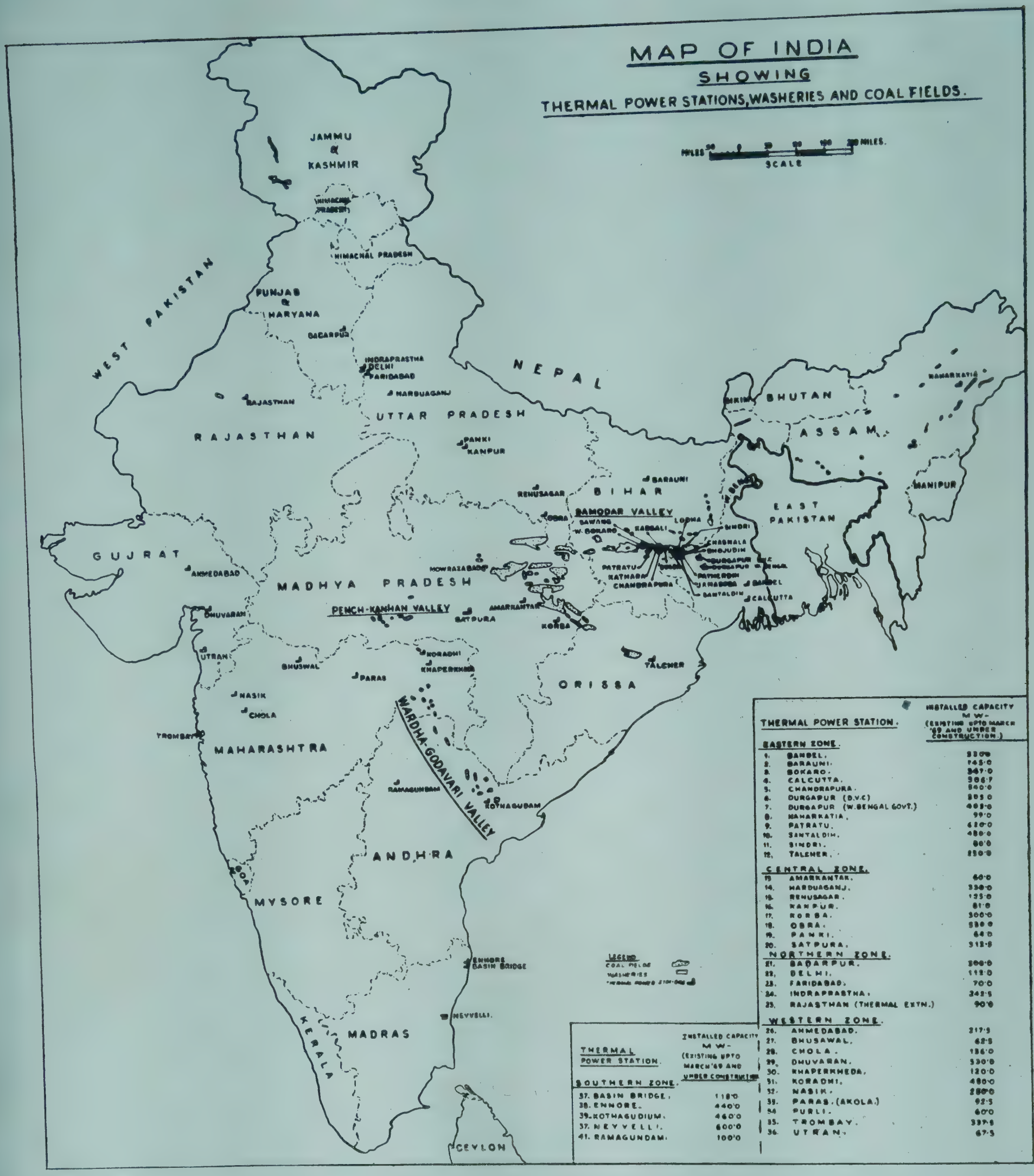
Fuel Quality and Major Design Features of the Boilers

The characteristics of the fuels used in the major power stations and other salient features of PF fired thermal power stations are shown in Table 1[3].

The ash percentage in fuel mostly varies between 30 and 40. Power stations for burning coals with 45 per cent ash have also been designed. Moisture in coal is low, being generally between 4 and 6 per cent. The ash fusion temperature is reasonably high, being above 1250°C for all the coals and above 1400°C for a good many.

L POWER STATIONS

Analysis, %		Hardgrove index	Fineness of powdered coal	Problems of power station
Ash	Sulphur			
35·6 (max.)	—	—	65-70%, −200 mesh	Erosion observed on super heater tubes, superheater enclosure screen tubes, air heater, I.D. fan blades and mech. dust collection equipment, excessive everywhere
28-30	0·6	—	80%, −200 mesh	Wear and tear on pulverizer; nothing abnormal
32·5-36·5	—	60-70	60-80%, −200 mesh (ASTM)	Severe wear and tear observed on pulverizer lining, vanes and balls, heavy erosion observed in cyclones
28 (max.)	—	50	above 70%, −200 mesh	Heavy wear and tear of pulverizer internals but not abnormal; heavy erosion found in mech. dust collectors
41·4 (max.)	0.47	59-65	80%, −200 mesh	So far no erosion observed, wear on pulverizer normal
25	0·6	55-64	50-60%, −200 mesh	Heavy wear and tear on pulverizer, burner tips, I.D. fan dampers and vanes
38·0	0·6	—	—	Slight erosion and corrosion in the mechanical precipitators
29·4	1·4	—	—	Erosion observed only in carrying pipe lines
14·5-19·0				
5·3-7·2	0·8-1·2 (dry basis)	110-120	—	Erosion not appreciable (av. life of hammer mill is 1000 hr)
31·5	0·74	—	70%, −200 mesh	—
38·0	—	—	80%, −200 mesh	Heavy erosion of PF carrying pipes to burners, whose tips are heavily eroded, ID fan blade and bowl mills are considerably damaged; erosion on bowl mills is significant
24·0-28·0	—	—	—	—
39·5	0·38	—	75%, −200 mesh	—
20·0-22·0	nil	—	75-80%, −200 mesh	—
25·0-30·0 (45·0)	—	above 50	80%, −200 mesh	Heavy clinker trouble



THERMAL POWER STATION.	INSTALLED CAPACITY M.W. (EXISTING UPTO MARCH '69 AND UNDER CONSTRUCTION.)
EASTERN ZONE.	
1. BANDEL.	330
2. BARAUNI.	145·0
3. BOKARO.	347·0
4. CALCUTTA.	306·7
5. CHANDRAPURA.	140·0
6. DURGAPUR (D.V.C)	185·0
7. DURGAPUR (W.BENGAL GOVT.)	40·0
8. MAHARKATIA.	99·0
9. PATRATU.	420·0
10. SANTALDIH.	480·0
11. SINDRI.	80·0
12. TALCHER.	250·0
CENTRAL ZONE.	
13. AMARKANTAK.	60·0
14. HARDUAGANJ.	330·0
15. RENUSAGAR.	125·0
16. PANKI.	81·0
17. KORBA.	300·0
18. OBRA.	280·0
19. PANKI.	64·0
20. SATPURA.	312·5
NORTHERN ZONE.	
21. BADARPUR.	300·0
22. DELHI.	112·0
23. FARIDABAD.	70·0
24. INDRAPRASTHA.	242·5
25. RAJASTHAN (THERMAL EXTN.)	90·0
WESTERN ZONE.	
26. AHMEDABAD.	217·5
27. BHUSAWAL.	62·5
28. CHOLA.	136·0
29. DHUVARAN.	330·0
30. KHAPERKHEDA.	120·0
31. KORADHI.	480·0
32. NASIK.	280·0
33. PARAS.(AKOLA.)	92·5
34. PURLI.	60·0
35. TROMBAY.	337·5
36. UTRAN.	67·5

THERMAL POWER STATION.	INSTALLED CAPACITY M.W. (EXISTING UPTO MARCH '69 AND UNDER CONSTRUCTION.)
SOUTHERN ZONE.	
37. BASIN BRIDGE.	110·0
38. ENNORE.	440·0
39. KOTHAGUDIUM.	460·0
37. NEYVELI.	600·0
41. RAMAGUNDAM.	100·0

FIG. 2 — MAP OF INDIA SHOWING THERMAL POWER STATIONS, WASHERIES AND COALFIELDS

Volatile matter is usually between 20 and 30 per cent, which is sufficient to ensure smooth ignition and combustion. The fineness of pulverization is such that 60-80 per cent of the ground material passes through a 200 mesh BS sieve. The hardgrove grindability indices of the coals are between 50 and 70.

The chief mineral matter in the coals is kaolinite with small amounts of pyrites and calcite. The mineral matter often contains abrasive materials like free silica and siderite, besides pyrites. Sulphur in most of the coals is generally below 0·7 per cent and organic in nature excepting for a few Madhya Pradesh and Assam.

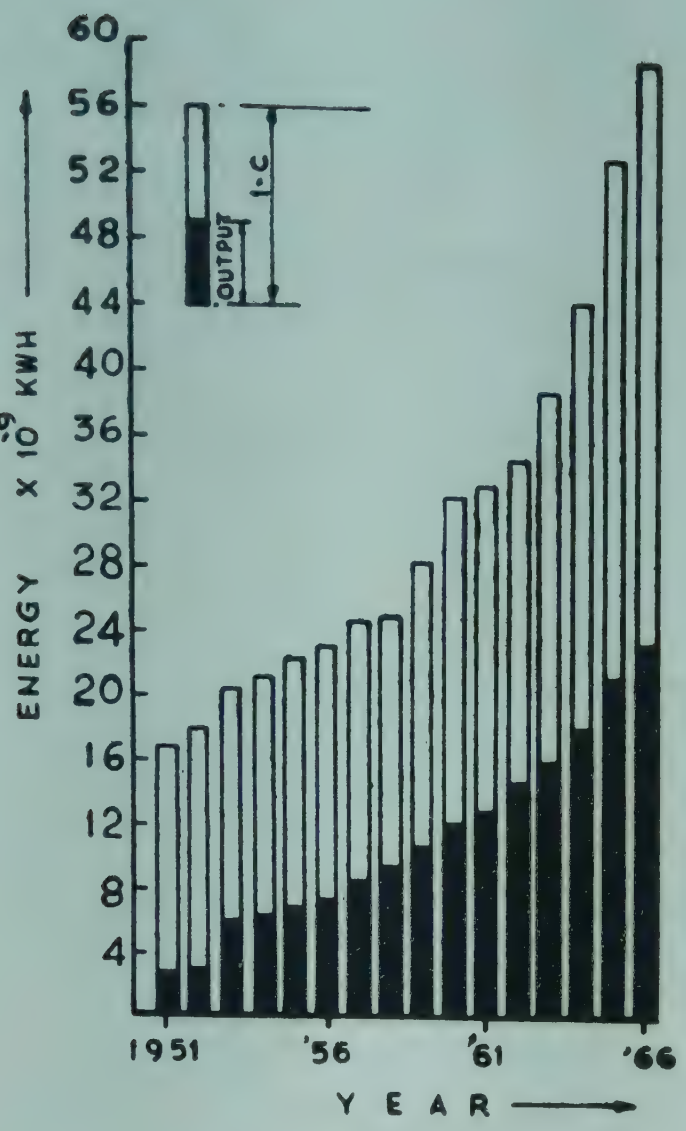


FIG. 3 — INSTALLED ENERGY GENERATION CAPACITY AND ACTUAL OUTPUT OF THERMAL BASED ELECTRIC POWER (1 kW INSTALLED CAPACITY =8760 kWh/YR)

coals where pyrites are present. Phosphorus usually varies between 0·05 and 0·2 per cent and only in a few cases it exceeds 0·24 per cent. The concentration of alkalies (expressed as Na_2O+K_2O) is usually of the order of 0·2-0·6 per cent. Chlorine is practically absent in all coals. Similar is the case with arsenic and boron.

Unlike bituminous coals, the lignite used in Neyveli power station has very high moisture and is characterized by lower ash fusion range and higher sulphur and alkaline earth contents.

The refractory nature of the ash of the Indian coals and high heat losses associated with wet bottom operation, particularly when the ash content is high, have led to the adoption of dry bottom furnaces. The furnaces are either corner fired or wall fired. Wide tube spacings have been provided to minimize erosion of tubes by high dust burden in gas. Velocities of the order of 50-60 ft/sec. in the high temperature section and 20-30 ft/sec. in low temperature circuit are characteristic features of many of the designs. Although the moisture in coals is between 4 and 6 per cent only, the surface moisture is liable to reach 15-20 per cent in rainy seasons and accordingly provision for pre-heating the air to higher temperatures has also been provided in the designs. Considering that a major factor affecting wear in pulverizers is the speed of the moving parts in the mills, and taking into account the hard nature and unfavourable grinding characteristics of Indian coals, either medium speed ring mills or low speed ball mills have been provided in the new major installations.

Our Power Station Problems

From Table 1, it appears that the most severe and common problem encountered by a large majority of the power stations is the heavy erosion of different units, right from the coal pulverizer to the ID fan venting the combustion gases into the chimney. In addition to the serious erosion problem, inefficient combustion and its attendant troubles arising out of wear of equipment and other uncontrollable lapses — both operational and maintenance — are believed to be responsible for low boiler availability and efficiency in some of the power stations. Slagging troubles accompanied by fused type deposit formation have also been reported for a limited number of power stations.

Two other problems, though not connected with boiler availability or efficiency, merit serious consideration: one is the disposal of fly ash and the other the atmospheric pollution by exhaust chimney gases.

High ash content of the fuels and its bad quality as also inconsistent and under specified fuel supply are considered by many power plant authorities to be mainly responsible for the present maladies in boiler plants. Other factors are improper functioning of units due to underspecified design for the prevailing operating conditions or lack of suitable spares or similar lapses. The inevitable drop in efficiency and availability with the ageing of the boiler should also be taken into account.

Spontaneous combustion during storage is another problem. Proper precautions against it cannot be incorporated either due to inadequate storage or handling facilities or irregular supply. Some of the coals even crumble to dust on storage causing dust nuisance, handling problems and fuel loss.

In countries abroad, great emphasis is laid on research and development aspects of

PF firing and its accompanying problems. The results of new developments for overcoming boiler troubles find their way to commercial practice through laboratory, pilot plant and field trials in succession. In Australia, besides laboratory investigations and rig tests, actual boiler trials are taken for obtaining prior knowledge about the likely behaviour of a particular coal in practice. Development of non-conventional technique for generation of cheap power from fossil fuel has also been receiving great attention and success achieved so far is significant.

R & D Work Abroad on PF Firing and New Routes for Generation of Power from Coal

PF Firing

Combustion Problems — The major part of investigational work in pulverized fuel combustion is directed at studying the flame characteristics and the factors affecting heat absorption in furnace[4-6]. Basic studies on combustion mechanism of pulverized coal and model studies on pulverized fuel combustion are two other important items of research.

Other subjects of research in allied areas include fuel storage and spontaneous heating, design of fuel bunkers and fuel feeders, methods for distribution of fuel to burners and improvements in burner design.

Deposit Formation and Corrosion Troubles— The most serious problem confronting boilers is the external fouling of boiler tubes by deposit formation and corrosion. Considerable work on causes and prevention of boiler deposit formation and corrosion have been carried out[7,8].

Fused slag deposits occur mostly on the hottest part of the boiler. The composition of the fused deposit is different from the original coal ash and is rich in iron oxide which gets sintered easily in presence of lime and silica. The bonded type deposits formed on water tubes and superheater tubes arise if the fuel contains objectionable amounts of sulphur, phosphorus, chlorine and alkali. The alkali matrix type of bonded deposit consists mainly of particles of fly ash bound in a matrix of sulphate or pyro-sulphate of the alkali metals while phosphatic type bonded deposits arise by the action of phosphorus compounds of alkali. Phosphatic deposits, however, occur rarely. Air heaters are some times choked by accumulation of loose black or grey dusts composed of a mixture of fly ash and sulphuric acid. Hard economizer deposits in the form of sulphate or phosphate occur only in very rare instances.

The constituents responsible for deposit formation can also lead to corrosion. Recent studies show that fireside corrosion is dependent on the formation of fused ash over a layer of alkali metal sulphate or chloride, and amongst alkalies, potassium plays a more damaging role compared to sodium[7].

Overheating of tubes resulting either from direct flame impingement or high local gas temperature is one of the primary causes of deposit formation in the high temperature section. Adjustment of flame shape or direction may be tried as remedy but this is again influenced by fineness of coal and its distribution in burner systems or burner designs and settings. Inefficient absorption of heat by tubes is another cause for overheating and in this context a proper check on the cleanliness of the internal surface merit attention. Other special means adopted for controlling temperatures in furnaces include humidification of combustion air and tempering of hot flue gases with cooler gases obtained from economizer exit.

Relief from corrosion trouble by increasing the excess air and by fitting deflectors to guide part of the clean secondary combustion air along the wall, blanketing it from flame impingement has been achieved in some PF fired stations. The oxidation of SO_2 to SO_3, primarily responsible for bonded deposit trouble and corrosion, can be prevented by lowering the amount of excess air or temperature. In oil firing, the latter course is usually adopted but in PF firing where the excess air is already in the level of 20-25 per cent, a moderate increase in excess air can help controlling temperature so that the SO_3 content does not rise appreciably. Too much lowering of temperature is also harmful as it may reduce the temperature of the metal surface or the combustion products below the acid dew point of the gases and help corrosion. In the prevention of low temperature corrosion, sensitive techniques for routine measurement of SO_3 and acid dew points are required. Equipment for recording SO_3 content continuously for concentrations down to 0·005 ppm has been developed[9]. Chemical treatment of heat transfer tubes and use of additive for combating fouling

problems have been tried successfully in many installations but many of these techniques are mostly either selective for particular boilers tested or have short-lived effect.

Erosion — Erosion in units from coal preparation stage up to the point of injection of coal-air mixture to furnace is, however, different from that in furnace and subsequent units. In the former, coal or more specifically certain mineral constituents of coal is the cause while in the latter the trouble is due to fly ash comprising a mixture of incinerated mineral matter and devolatilized coal. Nature and concentration of mineral matter in the gas and its velocity are the important factors in erosion. The fly ash of a dry bottom PF furnace carries with it 80-85 per cent of the total ash in coal and its process of formation is characterized by quick heating of coal to high temperature in a short residence time of 1-2 sec., while the degree of completion of combustion controls mainly its carbon content.

Extensive basic studies on the cause of erosion in coal pulverizers were undertaken at the BCURA, UK[10,11]. The major cause of wear in ball or rolls is abrasion. The action of an abrasive particle on a grinding element comprises first an elastic deformation, followed by plastic deformation when the load is sufficiently high. Of the mineral constituents in coal, quartz and pyrites are very hard minerals and break to produce sharply angular fragments and these two are considered to be most harmful regarding abrasion. Some workers have reported the existence of direct correlation between the alpha-quartz content of a sample and its abrasive index[12]. Interaction of quartz and pyrite, when present together, can lead to more serious erosion than can be anticipated from wear potential of the individual components. Siderite and calcite can also cause damages if the grinding elements are softer. Muscovite, kaolinite or illite in coal are not harmful and under certain conditions one or more of these minerals may help in decreasing wear by acting as lubricant. With the present system of size classification used in coal pulverizers, the mineral matter in coal having higher specific gravity than the coal substance itself is liable to accumulate in pulverizer for aggravating wear problems. Wear rate plotted against logarithm of micro-indentation hardness shows well-defined relationship, but any such well-defined relationship is non-existent between wear potential and Hardgrove Grindability Index.

Work on practical aspects of combating erosion problems in pulverizing mill and firing equipment in boiler plants using high ash coals has been reported from Japan[13]. The service life of rollers and rings of bowl mills could be extended satisfactorily by using chilled chromium martensitic white cast iron. The problem of serious blade erosion of exhauster fan was successfully solved by developing finned and serrated types of blades. Use of martensitic white cast iron and of extended peripheral thickness at bends proved to be helpful in minimizing wear of PF pipelines.

Erosion of boiler tubes and superheater tubes arise mostly from improper location or wearing out of baffles, or leaks in internal joints or sudden reduction in cross-section and the remedy lies in proper design and disposition of tubes and baffles, streamlining bodies of U-belts on tubes and correct disposition and operation of soot blowers and proper maintenance. The provision of suitable impingement type coarse separators on the rear screen tubes is reported by M/s Mitsubishi Heavy Industries Ltd to have helped in reducing fly ash erosion of superheaters in a Japanese boiler[13].

With mechanical dust collector and electrostatic precipitator working efficiently, the separation of fly ash should be quite satisfactory and ID fan should have very little erosion problem. The improper functioning of the units may be due to underspecified design or wear of the equipment themselves. Studies at CERL, UK, have shown that uniform distribution of flue gas, application of highest possible voltage, arrangement for rapping the different parts of the precipitator when the dust has built up to about $\frac{1}{8}$ in., rapping by impact instead of vibration, and automatic control are factors conducive to obtaining high efficiency in precipitators[7]. The electrical resistivity of the fly ash appears to play an important role in fixing the efficiency of the precipitator and when the resistance of the dust exceeds 10^{11} ohm/cm, the efficiency of the precipitator is reduced[14]. Low sulphur content of coal and inadequate conversion of SO_2 to SO_3 are considered to be important factors for giving rise to high-resistivity dusts. The injection of SO_3 to flue gas stream prior to precipitator has helped in improving performance of precipitators working with high-resistivity

dusts. The SO_3 injected remains completely absorbed in dusts. Enriching the coal with limestone is also reported to have improved precipitator efficiency. Other important factors affecting the precipitator efficiency are the particle size and shape, concentration of particles smaller than 5 microns and irregular or angular shapes of particles[16]. It is also believed that a suitable precipitator singly can serve the purpose better than the combination of a precipitator and a cyclone. Development work for building up of precipitators suitable for placement before cyclone, contrary to normal practice, is also in progress. In this type of combination, the precipitator functions primarily as a coagulating unit for the very fine particles. Electrostatic precipitator for operating at temperature as high as 1500°F and at pressures of up to nearly 1000 psi has already been developed, and this opens the avenue of combating erosion problem in boilers with precipitator even in high temperature zones.

Fly Ash Disposal

Over the last decade or so, research work in the area is primarily directed towards development of avenues for utilization of fly ash in various types of building and civil engineering work. In 1965, USA produced 20 million tonnes of fly ash but only 2·5 per cent of it could be utilized, while the second largest producer, Germany, utilized 26 per cent of its total production of 10·4 million tonnes of fly ash in the same year[17].

Choice and Development of Suitable Materials for Boiler Elements

Regarding the choice and development of suitable materials for boiler elements, investigations on superheater tubing material in contact with combustion atmosphere show that 25 per cent Cr, 12 per cent Ni stainless steel and 25 per cent Cr, 20 per cent Ni stainless steel undergo minimum metal loss and subsurface attack. In Germany, austenitic steels with Cr/Ni ratio of 16:13 and 16:16 have gained favour for steam temperatures above 1050°F[18].

New Methods for Generation of Power from Coal

Parallel with research and development activities in the field of PF firing, search for new routes for generation of cheap power from coal is going on vigorously. A scheme contemplating total gasification of coal under pressure in slagging operation and subsequent combustion of gas in pressurized boiler with provision for depressurizing the exhaust gas in a turbine for supplying compressed air to the boiler can lead to a design efficiency of 41-42 per cent against 38 per cent[19], the maximum, currently obtainable from conventional steam cycle. The development work now in progress for Magneto-Hydro-Dynamics (MHD) and Electro-Gas-Dynamics (EGD) processes hold promise for considerable reduction in power costs and also prospects of cheap power generation in large baseload units. The techniques stated above are, however, fairly long range projects and a number of hurdles remain to be overcome before their industrial adoption.

The recent development of fluid bed combustion boiler is in a well-advanced stage and holds promise for immediate application in industry for generation of low cost steam and power from low grade coals. The process, in essence, consists of combustion of coarse sized coal (say 6 mm-0) in a fluidized bed of refractory with heat transfer tubes in bed. In this technique advantage is taken of the very high heat transfer rate possible between the bed material and heat transfer tubes and this advantage coupled with the feasibility of high heat release rate enables a drastic reduction in cost and size of heat transfer tubes and boiler. The process does not require any fine grinding of coal and can burn fuels efficiently with ash content up to 90 per cent — a feature hitherto inconceivable for any conventional steam raising technique. Further, the process operates at only 800-900°C, being roughly 200°C below the initial deformation temperature of ash and thus deposit and corrosion troubles are minimized.

Intensive research and development work are under way both in USA and UK and also in Australia and the great measure of success already achieved can be gauged from the fact that development of fluid bed combustion boiler has almost reached the threshold of industrial application[20]. In the British practice, the heat transfer tubes are kept immersed in the fluidized bed while in the American version of the process, the heat transfer tubes are kept in direct contact with the bed only at side walls of the furnace. In UK, pressurized fluidized

bed combustion is also being developed to gain the advantages inherent in pressure operation as also to utilize the energy in pressurized exhaust flue gas from boiler for driving a turbine. Active study of this technique has been taken up at the CFRI and success has already been achieved in testing its applicability to low grade Indian coals and lignite. Basic design data are also being collected for full scale units.

R & D Work in India on Power Station Problems

Combustion and Allied Problems — Studies in a 100-200 lb of coal per hr test rig coupled with boiler trials in a 25 MW boiler for the proposed fuels for future installations are necessary for studying the combustion characteristics of fuels and for predicting their performances in actual operation, and for establishing the influence of variation of steam quality on boiler performances. CFRI proposes to set up a test rig for studying the combustion behaviour of Indian coals in PF firing and other problems associated with it.

CFRI carried out actual plant trials in one of the spreader stoker boilers of Sindri Fertilizer Ltd.[21] to test their performance with middlings. The boiler was designed for better grade coals. The test showed that the boiler could maintain 90 per cent of the rated load and an increased fines content would help in maintaining the rated load with some loss in efficiency. Recently, on invitation by the plant authorities, the CFRI established through actual boiler trials that in an industrial-cum-utility stoker fired boiler located in west coast, cheaper coal from a nearby region in M.P. could be fired successfully in place of Raniganj coal transported from considerable distance[22].

The proper design of burners and their correct disposition as also improvements in firing techniques in the context of our special fuel characteristics also merit great attention. For some Indian coals, the volatile matter is only 20 per cent or even little below. With such coals, it is required to examine if vertical down-firing would be useful. Roof burners with U-flame path help in maximum separation of ash before convective heating surfaces are reached.

It was thought that cyclone firing, an advancement in PF firing, would perhaps be ideally suited for Indian hard, high ash coals. An 18 in. diameter axially fired cyclone furnace was designed and commissioned at the Institute for studying the behaviour of Indian coals. The studies have shown that due to the refractory nature of ash of the coals they were unsuitable for this process.

The Institute had also carried out considerable work on PF burner design and has developed two types of PF burners suitable for installation in the restricted combustion space of small vertical boilers.

Being alive to the proneness of our coals to low temperature oxidation and to weathering on storage, large volume of work on these subjects have been carried out at the Institute and at the different Survey Laboratories spread over the country. Actual stack trials have been conducted with Raniganj and M.P. coals to test their liability to spontaneous combustion.

Deposit and Corrosion Problems — Cases of corrosion and bonded deposit formation in Indian power plants are very rare. This is because most of the Indian coals contain small amounts of fouling elements, viz. sulphur, alkali, phosphorus and chlorine. There are, however, some coals containing fouling elements beyond the safe limit, and combustion of these fuels warrants investigations into the fireside corrosion problems. CFRI has been doing a systematic survey of the nature and amounts of fouling elements in different coals and their behaviour on heat treatment.

Instances of fused slag deposit formation have been noted in some of the boilers; the trouble was caused by improper operation of overfire secondary airjets and use of underspecified fuel.

Erosion Problem — This is the most serious problem for power stations in India and a joint effort of boiler manufacturers and designers, power plant authorities and research organizations dealing with fuel problems is needed to overcome it, as the solution of the problem involves proper design of the units, use of right type of abrasion resistant material at the right place, proper operation and maintenance schedule and supply of the right type of fuel.

The quality and quantity of the mineral matter in the fuel, the degree of fineness of pulverization, the nature and concentration of coarse particles in pulverized coal and the degree of completion of combustion all influence the extent of abrasion. Although provisions exist in some of the mills for partially separating harder materials at the

time of crushing and some proportions of the heavier constituents in the fly ash get settled in the furnace, yet the fly ash contains a harmful proportion of the abrasive materials including some unburnt carbon. A systematic study on the nature and concentration of dust in flue gas at important points as well as similar studies with regard to feed material at different stages of its processing will help in controlling boiler abrasion. An apparatus for measuring the relative abrasive indices of different samples is being standardized at the Institute. Studies at CFRI show lack of correlation between grindability index and ash content of our fuels. A study on the influences of both mineral matter quality and quantity in fuel on boiler abrasion is urgently needed.

It is well known that our coals are low in sulphur and in this context investigations on injection of SO_3 to flue gas stream prior to its entry to electrostatic precipitator or adoption of other means for improving the performances of precipitators merit attention for controlling ID fan erosion and atmospheric pollution problems.

In many instances, erosion problems have been tackled capably with indigenous materials and know-how. At Chandrapura Power Station, indigenous materials for peripheral and side liners of exhauster have been developed for replacing imported products and the life of the exhauster fan blade extended more than three times that of original design by welding ribs to the fan and proper maintenance and repair of the unit. The erosion of boiler tubes at Bokaro Power Station was successfully solved by eliminating the leaks in baffle plates responsible for the erosion[23].

Fly Ash Disposal — In 1970-71, the production of fly ash in India was about 4 million tonnes per year and by 1980-81, the figures will exceed 9 million tonnes. In the event no effective route for disposal of the fly ash is evolved, its dumping—the only route left for its disposal, will cost Rs. 18 crores in 1980-81.

Processes have been developed at CFRI for making high quality building bricks from fly ash[17]. The Central Building Research Institute is engaged in conducting investigations on utilization of fly ash as pozzolana in concrete, as portland pozzolana cement and light weight aggregate[24]. Ratnam *et al.* have studied the possibility of using lignite fly ash for building and civil engineering work[25]. It is reported that fly ash of lignite power station at Neyveli is being used for making pozzolana cement and for making hollow bricks. Further research work is being continued at many of the above centres.

Future Planning and Working of Power Stations in the Context of Fuel Situation

On the face of rising competition from oil and nuclear power on one hand, and transport bottleneck and high freight charges involved in long distance haulages on the other, the supply of right type of fuel to power stations located far away from coalfields merit special consideration. The CFRI considers that supply of washed low ash coals by pipe line transmission to distant power stations and burning of high ash refuse at the centre of coal preparation would perhaps be an effective answer to the challenging problem. A techno-economic study of the scheme is needed before implementation of the scheme.

Quality of fuels appears to be an important factor causing the low boiler availability. Considering our fuel resources, it is difficult to get away from using poor quality fuels. Developments of boiler designs, and operation and maintenance schedules to suit such fuels are most required.

It is generally found that capital cost of a plant reduce roughly by 20 per cent per kW if the size of the unit is increased by 100 per cent. It is also an established fact that an increase in steam pressure and temperature coupled with suitable provision for steam reheating helps in reduction of heat consumption per kW. As shown in Table 2, a boiler generating steam at 400 psi and 740°F and without any steam reheating will need 13500 Btu/kW, while a modern boiler operating at supercritical condition and generating steam at 4500 psi and 1050°F with provision for two-stage steam reheating will require only 8550 Btu for the same output of electrical energy. It thus appears that larger the size of the boiler unit and higher the steam pressure and temperature, the better would be the efficiency and lesser the price of electricity. Indeed, they would have been so, if we could assure firstly, sufficient availability of suitable boiler elements for such designs, and secondly, supply of proper quality fuel for ensuring high level of boiler availability and efficiency.

TABLE 2 —EFFECT OF STEAM PRESSURE AND TEMPERATURE AND OF REHEATING ON HEAT CONSUMPTION PER kWh

Sl No.	Pressure psi	Temperature °F	Steam cycle	Specific heat consumption Btu/kWh
1	400	750	Without reheat	13500
2	1500	1000	do	10000
3	1500	1000	With one-stage reheat	9500
4	2000	1050	do	8900
5	3500	1050	do	8680
6	4500	1050	do	8590
7	2000	1050	With two-stage reheat	8835
8	3500	1050	do	8587
9	4500	1050	do	8555

Acknowledgement

The authors express their sincere thanks to Dr A. Lahiri, Director, CFRI, for encouragement, guidance and varied discussions they had with him in the course of these studies. The authors also thank Mr S. K. Das Gupta, Deputy Director, Mr M. M. Sen, Scientist, and Mr S. K. Mazumdar, Scientist, for the help rendered by them in the preparation of the paper.

M. Banerjee, R. R. Biswas, J. R. Mitra & B. Acherjee

References

1. Lahiri, A., paper presented in the Symposium on Coal Mining Industry, MGMI — Coal Producers' Assocn, Calcutta, 1969-70.
2. Sinha, N. C. (private communication).
3. Majumdar, S. K. (private communication).
4. Baker, P. C. *et al.*, BCURA Information Circular No. 308, 1966.
5. *BCURA Annual Report*, 1966.
6. De Graaf, J. E. *et al.*, *The future of fuel technology*, edited by G. N. Critchley (Pergamon Press Ltd., London), 1964, 31.
7. Lucas, D. H., *J. Instn Fuel*, **36** (1963), 203.
8. Crossley, H, *J. Instn Fuel*, **40** (1967), 342.
9. Anon, *Steam & Heating Engr*, **39** (Oct. 1969), 14.
10. Hiorns, F. J. & Parish, B. M., *J. Instn Fuel*, **39** (1966), 126.
11. Parish, B. M., *J. Instn Fuel*, **40** (1967), 76.
12. Oda, T. *et al.*, Symp. on Steam Power Station India, *Indian J. Powr & Riv. Valley Devevelopt*, (1965), 165-173, 179.
13. Ishida, M. & Hashiguchi, M., ibid, 373-79.
14. Busby, H. G. T. & Darby, K., *J. Instn Fuel*, **36** (1963), 184-97.
15. Anon, Coal Research in CSIRO, No. 37, 1969, 8-14.
16. Research-Cottrell Inc., *Bulletin No.* 850.
17. Majumdar, S. K., *FRI News*, **19** (1969), 100-111.
18. Kant, R., *Indian J. Powr. & Riv. Valley Developt*, **16** (12) (1966), 23-32, 35.
19. Burdett, R. H. & Eaves, P. S. K., *J. Instn Fuel*, **36** (1963), 376-89.
20. Hangerbrauck, R. P. & Henschel, D. B., *BCURA Mthly. Bull.*, **33** (1969), 106-10.
21. Sen, M. M., Biswas, R. R. & Das Gupta, S. K., Seminar on Fuel Economy, Ranchi, 1964.
22. Sen, M. M. *et al.*, National Seminar on Fuel Efficiency, National Productivity Council, New Delhi, 1970.
23. Singh, R. N., *Indian J. Powr & Riv. Valley Developt., DVC Special Numbert* (1968), 39-51.
24. Monograph No. 1, *J. Instn Engrs, India*, 1965.
25. Ratnam, C. V. S. *et al.*, *J. Instn Engrs, India*, **44** (1966).

ABRASIVENESS OF COAL AND ASSOCIATED MINERALS IN RELATION TO PULVERIZER WEAR

DURING recent years, the demand for coal for power generation has gone up steadily. Energy experts all over the world believe that the electricity industry may provide wider markets for coal in future. In modern power stations, coal is used in pulverized form. The 'availability' of a grinding mill is determined by its rate of wear and conditions of operation, and the maintenance cost due to wear alone, apart from outage costs, is often more than the cost of power required for grinding[1]. Some general information is available on the wear resistance of metals and alloys but there is not much work reported on the abrasive and corrosive properties of the non-metallic minerals, especially in their association with coal. There is no standard method of assessing and predicting wear potentials of a coal in relation to a particular type of mill. The physics department of BCURA has conducted systematic experiments using, particularly radiotracer method of wear measurement; check experiments with an abrasion test machine have also been carried out. The methods and equipment developed at BCURA are designed to simulate the mechanical conditions in industrial pulverizers, especially in tube and vertical spindle mills, in so far as this can be done on the laboratory scale. This note incorporates a brief review of the work done so far and also the results of a factorial experiment involving a study of the effects of three variable factors on abrasion measurements by a weight-loss method.

Methods of Wear Measurement

The main cause of coal pulverizer wear may be abrasion, corrosion or a combination of these. The laboratory apparatus developed measures the amount of wear by the following two methods[2]:

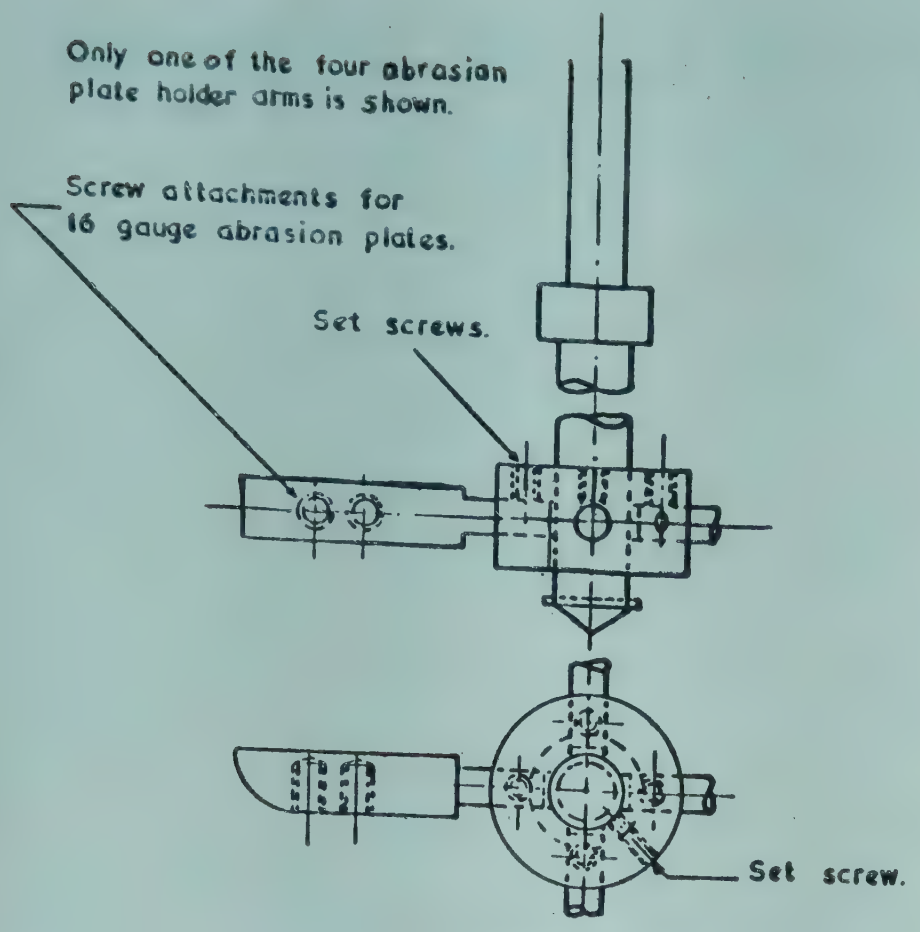
(a) *Weight-loss Method* — The apparatus is a modified version of the type developed by Yancey, Geer and Price[1] and consists of a cylindrical steel mortar that holds the coal sample and in which a shaft carrying four paddle arms is rotated by a drill press. Soft iron blades are fixed to the arms and the abrasion is measured as loss in weight after the blades have rotated for a fixed number of revolutions. Fig. 1 gives a sectional view. The conditions of operation are: The drill motor, 2·5 hp; speed of rotation, 1450 rpm; revolutions per test, 12000; weight and size of coal sample, 4 kg through 4 mesh (Tylor); clearance of blades from wall and floor, 0·2 in.

The blades are cleaned at the beginning of the day by metal polish and are weighed within 0·1 mg and assembled in the paddle arm. After each test, the blades are washed in water and acetone, dried with tissues and reweighed to within 0·1 mg. The Yancey-Geer-Price Index is simply the total weight loss in mg. An abrasion index (AI) also used in BCURA is calculated by comparing the weight loss with that lost in testing a standard coal, which is the West Midlands 2-yard seam (Newdigate hand picked) with AI taken as unity. This is one of the cleanest seams at present available with moisture content 10·2, volatile 30·0, FC 57·7 and ash 2·1 per cent. The most important feature is the low ash content, since it has been shown that the coal substance contributes little to the weight loss.

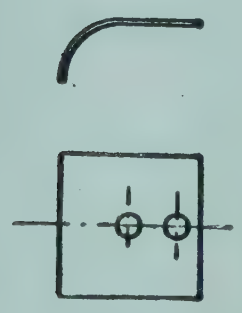
(b) *The Radiotracer Technique*[3] — In view of the large-scale use of tube mills and vertical spindle mills in power stations in the UK, the methods adopted at BCURA mainly simulate conditions in these types of mill. The results may, however, be indicative of the behaviour of hammer or attrition mills. A laboratory ball mill may be considered as simulating conditions in tube mills and a roll crusher for a vertical spindle mill. The major part of the experiments at BCURA is, however, restricted to a roll crusher apparatus, work with the ball mill was limited to development of the technique.

The Roll Crusher Apparatus

A sectional view of the apparatus is shown in Fig. 2. A schematic representation of the roll crusher experiment is given in

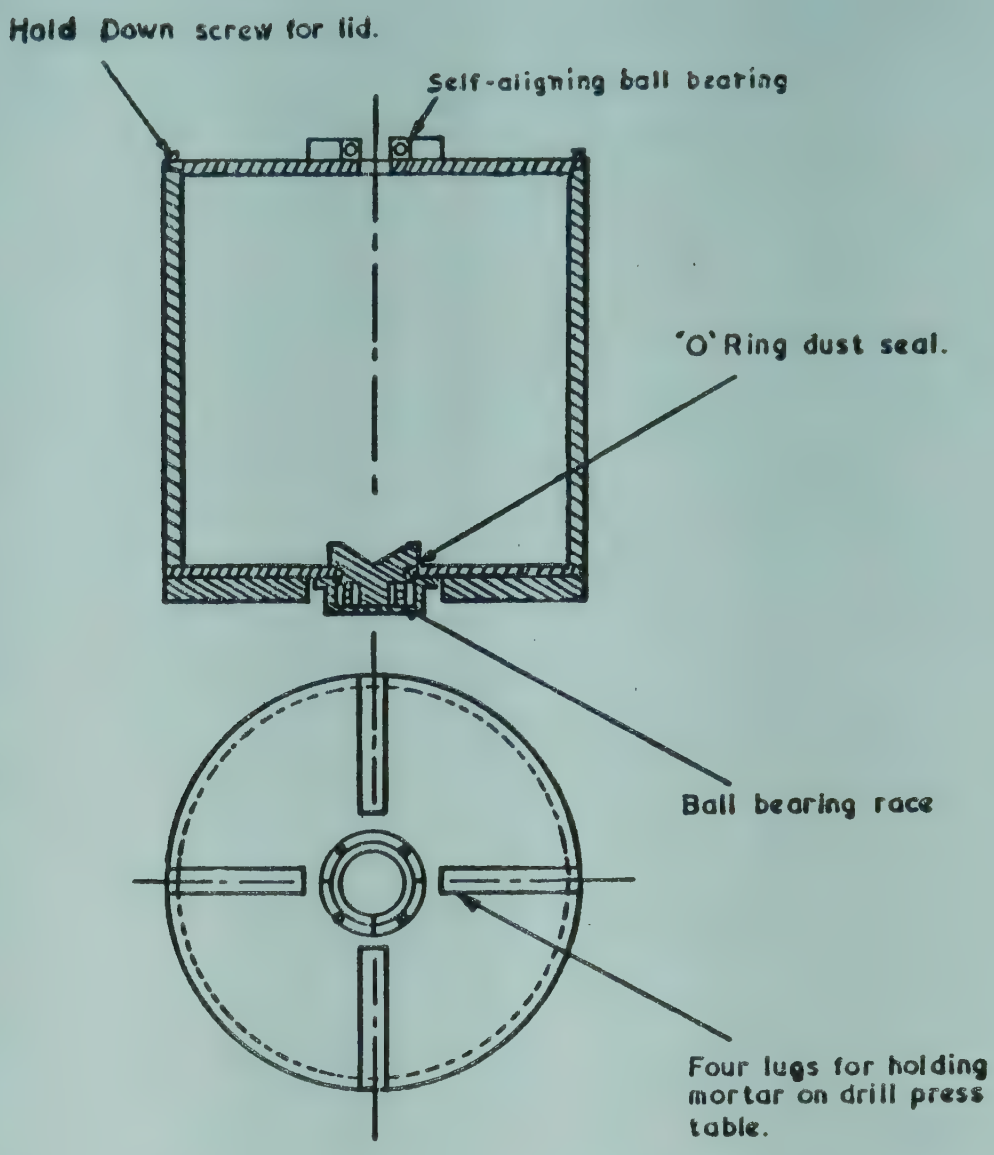

Only one of the four abrasion plate holder arms is shown.
Screw attachments for 16 gauge abrasion plates.
Set screws.
Set screw.

Shaft and Arm



Abrasion diode

1a


Hold Down screw for lid.
Self-aligning ball bearing
'O' Ring dust seal.
Ball bearing race
Four lugs for holding mortar on drill press table.

1b Mortar

FIG. 1 — DESIGN OF MODIFIED ABRASION TEST MACHINE

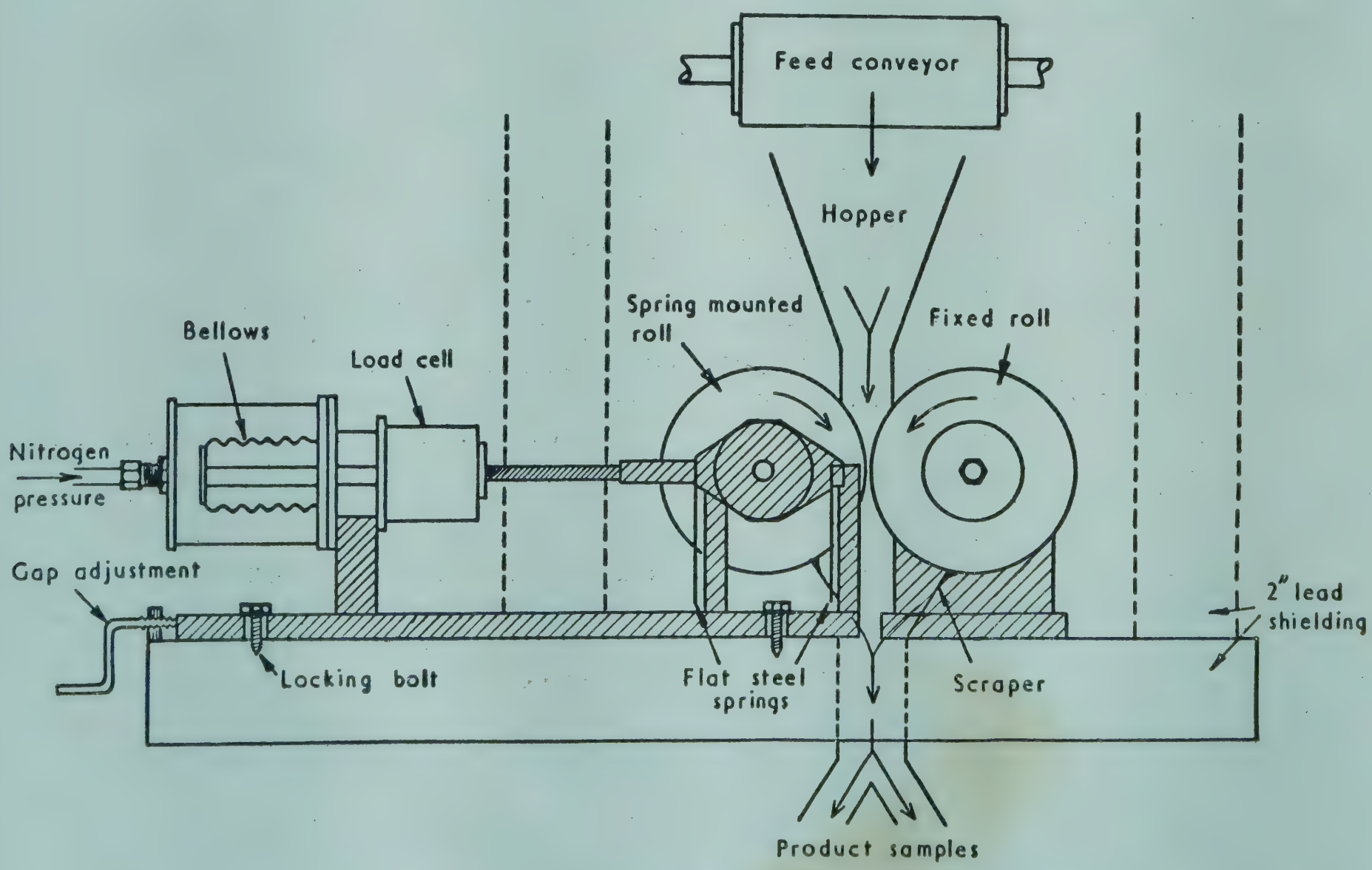


FIG. 2 — DIAGRAM OF ROLL CRUSHER APPARATUS (NOT TO SCALE)

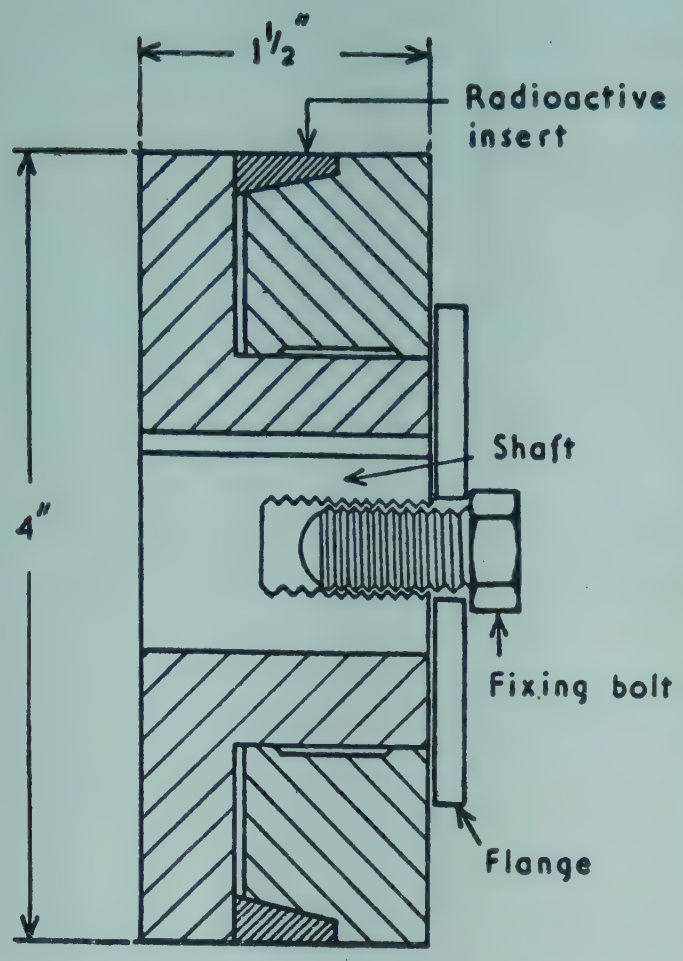


FIG. 3 — CROSS-SECTION OF ROLL SHOWING IRRADIATED INSERT

Appendix I. The coal is ground by a pair of rolls of 4 in. diameter and $1\frac{1}{2}$ in. width each. One of the rolls is made in three parts to provide an insert which is irradiated. This insert thus comprises a radioactive ring representing $\frac{1}{6}$ of the total grinding surface area, and made from the same metal as the rest of the rolls. A cross-section of the roll containing the insert is shown in Fig. 3. The iron isotope Fe^{59} emitting gamma-radiation can be assayed by a scintillation counter at a sensitivity of 10^{-3} g, which is adequate for the order of wear rates found for a period of several half lives of the isotope. For comparative purposes, sensitivity can be taken as 10^{-4} g. The wear rate is thus obtained by determining the amount of radioactivity in the wear debris in the product. The apparatus can be used to study the effects of variable factors like feed rate, roll speeds, mechanical load and the gap between the rolls. The ground product containing the radioactive wear fragments is divided into two parts. One part is reduced in volume by ashing first at 400°C and then by raising the temperature to 700°C for 4-5 hr. The ash is then compressed to a standard geometry before the radioactivity measurement is made. A sieve analysis is done on the other part to assess the amount of fines production.

The range of operation and standardized conditions of the apparatus are:

	Range of operation	Standard conditions
Load on roll	0-60 psi	40 psi
Roll speed	460-2000 rpm (in 12 steps)	460 rpm
Feed rate	5-30 kg/hr	15 kg/hr
Gap between rolls	0-$\frac{1}{4}$ in.	zero
Coal per test	—	1 kg through $\frac{1}{4}$ in.

The rolls are independently driven so that differential speeds can be used. The number of counts are converted to total weight of wear debris by a preliminary calibration and wear rates are computed in respect of a scale up to industrial equipment. A suitable computer (ALGOL) programme[4] for the purpose has also been developed; this incorporates a variety of correction, e.g. shielding, decay, geometry, to the count. The wear rate in mg per kg of coal ground, called the standard wear rate, and the wear potential is defined as the wear rate divided by the percentage of fines (usually —200 mesh) produced, i.e.

$$\text{Wear potential (WP)} = \frac{\text{wear rate (mg/kg)} \times 100}{\%\ \text{minus 200 BS produced}}$$

Both the methods have their own limitations and advantages. The weight loss method is speedy and inexpensive but in the case of high abrasive material, the wear rates will be so high as to require frequent replacements of the soft iron blades[5]. The degree of perfection in cleaning the blades after each test will decide the accuracy and reliability of the results. *This may, however, be used as a rough and ready method of selecting coal for a power station.* More seriously, the method does not detect particle size and other effects shown to be important in the roll crusher experiments.

The radiotracer technique is very versatile but expensive; a large number of determinations can be made in a short period of time. Moreover, different regions of a sliding surface may be made radioactive and one can carefully monitor the wear debris and compare the rate of wear in different regions. However, in the case of heavy wear, the

extreme resolution of the radioactivity can overload the counter unless the sample is diluted. It has also been reported that abrasive wear can be influenced by section thickness and cooling rate, and the properties of a thin section, such as that used in the laboratory, may not be comparable with those of the commercial grinding element.

Factors Affecting Abrasiveness and Mill Wear[6]

The following factors are thought to be responsible for mill wear: (a) the breakage forces, (b) the nature of feed-coal and associated minerals, and (c) the material of construction of grinding element.

(a) *The Breakage Forces* — The forces used for breakage, per unit area of working surface, depend on the type, load and speed of a mill and also on the extent of recirculation of the material for regrinding. For example, in a tube mill, the operating conditions are governed by its capacity, speed, quantity, type, size distributions and feed rate of the coal; extent of air sweeping and the temperature distribution inside the mill. As the balls are lifted and subsequently thrown back on the base, impact forces induce size reduction and wear. Moisture in the coal aided by temperature variation inside the mill and the chemical reactivity of the feed may also lead to wear due to corrosion. On the other hand, in vertical spindle mills, size reduction is done by crushing and shearing due to which the major cause of wear is abrasion. Corrosion is less likely to take place because a more effective drying process is used.

Classification may produce several effects through altering operating conditions, e.g. (i) lowering of the general moisture level, (ii) the associated minerals due to their higher density need finer grinding than the coal before they can be removed by air elutriation systems, (iii) because of (ii) and as many of the associated minerals are harder than coal, there must be a concentration of minerals within the mills. The composition of the new feed will, therefore, be different from the effective composition of the material passing through the grinding element.

(b) *The Nature of Feed*: (i) *Coal* — In so far as coal causes wear, this is related to its hardness. Hardness is a complex property describing the behaviour of the material under compound stresses. The hardness of coal (Vickers) of different ranks is quoted below:

	HμV
Low rank	15-30
Non-coking coal	30-45
Coking coal	20-30
Semi-anthracite	60-70
Petrographic constituents	10-230

Anthracite is so elastic that there is no permanent indentation using microhardness techniques. Coals used in power stations in some countries cover a wider range of rank from the highly caking variety (carbon dmmf 86-92, HI 60-85) to completely non-caking (carbon dmmf 78-84, HI 45-55). It is, however, concluded that since the coal substance is very soft in comparison with some of the associated impurities, its contribution to wear is small, so the effect of change of rank or petrography is unimportant from the point of view of pulverizer wear.

(ii) *Properties of Associated Minerals*[7] — The adventitious and 'inherent' minerals can be divided into six major groups. The properties such as hardness, cleavage particle size, etc., of representative minerals of each group (from the point of view of mill wear) are discussed below, in so far as they concern British coals:

Group	Representative minerals
M — shale	Muscovite, illite
K — kaolin	Kaolinite
S — sulphide	Pyrite
C — carbonates	Calcite, siderite
H — chloride	Halite
A — accessory minerals	Quartz

The presence of the minerals may affect mill wear in one or more of the following ways: the amount of mineral present, surface properties and interactions, etc., the hardness of the minerals relative to that of the grinding element specific gravity, particle size and shape. Abrasion being one of the major causes of wear, it is important to note that for a material to scratch another, it must be at least 20 per cent harder. The minerals due to their variability of chemical composition and hardness anisotropy exhibit a range of hardness.

M and K Group — Muscovite can occur in plates up to 200 μ across but in less than 50 μ particle diameter. Illite occurs as flakes with less than 20 μ dia. These groups of minerals are extremely soft, being about 2-2·5 on Moh's scale. Considering surface properties and mode of occurrence, it is concluded that these minerals are not likely to produce enhanced wear; on the other hand, due to lubrication effects, they may often be the cause of reduction of machine wear per unit time, although not necessarily per unit of feed ground to a specific size.

S Group — Pyrite occurs as large lenses, nodules, as thin sheets in cleats and joints or as finely disseminated particles which may be cubes crystallized *in situ*, and for which the average particle diameter may be 10-40 μ, although aggregates may exceed 1000 μ. In Moh's scale, it has a hardness of 6-6·5, a microhardness (Vickers) of 850-1150 HμV with variations as high as 1700 HμV. In this context, the Brinell hardness of 450-550 (equivalent to 600-750 HμV) of a typical alloy iron (Nihard) used for grinding elements and also of coal substance 45 HμV (max.) need to be considered. Pyrite has no marked cleavage planes and breaks with a conchoidal fracture to form sharply angular particles. Moreover, the specific gravity (4·8-5·1) is higher than most of the other associated minerals. Since the classification process rejects oversize on a density basis, pyrite must be ground considerably finer before it can pass through the classifier. The difficulty of breakage and the high specific gravity thus increase its concentration in the grinding zone. Under typical conditions, pyrite is readily oxidized with ultimate production of H_2SO_4 which causes serious machine wear in the presence of abrasion.

C Group —Calcite occurs as small rhombs, as thin sheets in cleats and joints or as a cementing material. Siderite occurs as nodules and in bands associated with other minerals. The grain size may be up to 50 μ. The hardness of calcite is 100-200 HμV and of siderite 430 HμV. With hardened grinding elements in a vertical spindle mill, calcite and siderite are not likely to have marked abrasive effects but where the balls are of 200-250 HμV as in tube mills, siderite might produce appreciable wear. Both the minerals exhibit perfect rhombohedral cleavage. Angular siderite particles might affect tube mills.

H Group — Halite is very soft with 19-47 HμV. Soluble chlorides promote corrosion

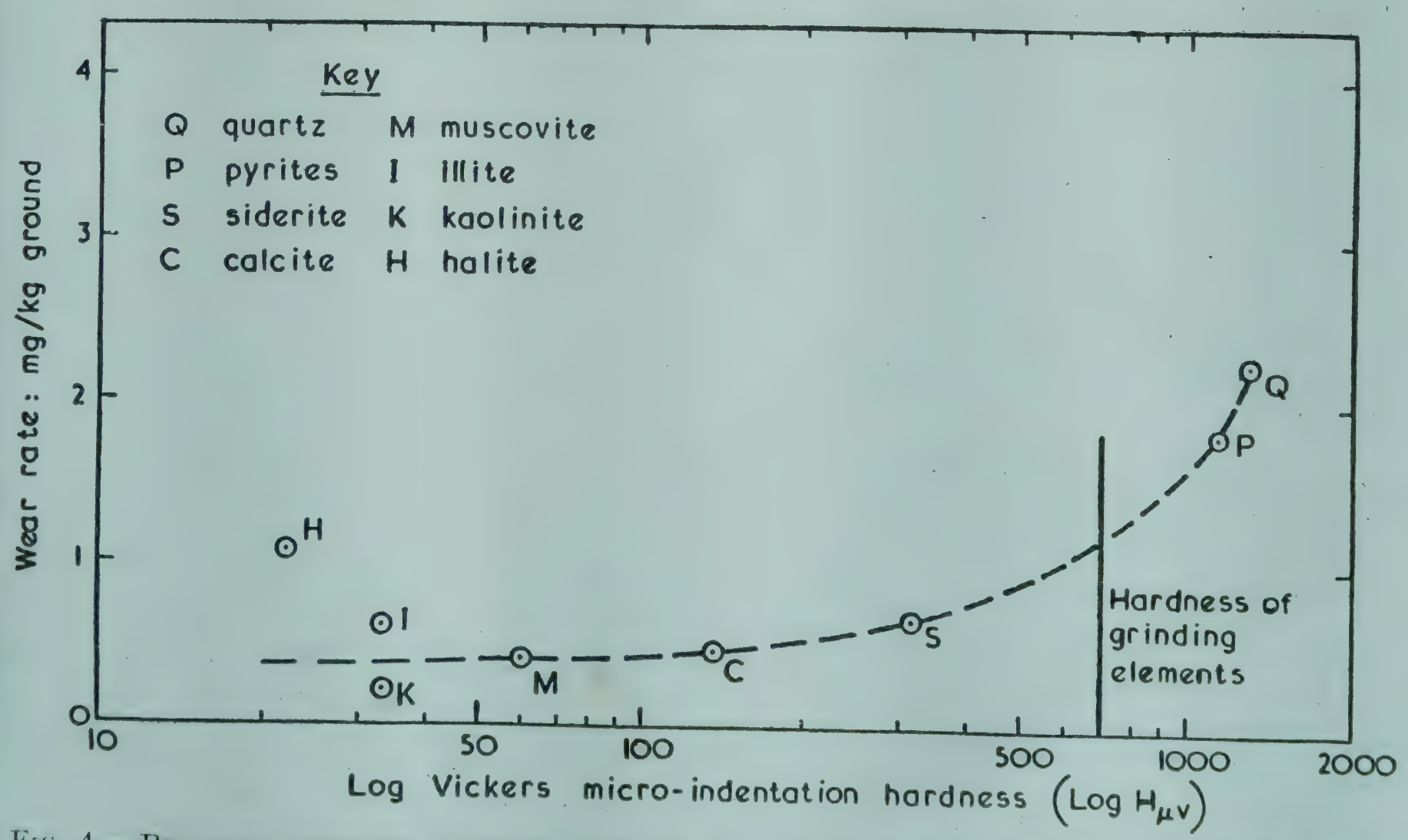


FIG. 4 — RELATION BETWEEN MINERAL HARDNESS AND WEAR RATE [THE HARDNESS VALUESS PLOTTED ARE MEAN VALUES, OBTAINED BY THE ASSOCIATION, 10 PER CENT OF EACH MINERAL WAS ADDED TO A CLEAN CARRIER COAL AND PASSED THROUGH THE ROLL CRUSHER]

and thus reduce the resistance of the grinding element to wear by other minerals.

A Group — Quartz occurs as rounded or sharp angular grains. In shales, it is less than 100 μ but it may otherwise occur as large as $\frac{1}{16}$ in. It has a mean hardness of 1300 HμV as against 1130 HμV for pyrite, although both show appreciable spread. Due to the higher specific gravity, build up inside the mill is probable. Quartz is stable in all atmospheres and thus does not induce corrosion.

(c) *Material of Construction of Grinding Element* — The most effective method of minimizing wear is by correct selection of grinding element material. But the choice is limited due mainly to availability and machinability, to the engineering design of the mill and the feed. The criteria that may be used in selecting a material are hardness, elastic-plastic behaviour, microstructure and corrosion resistance. The grinding element materials, presently in use, have hardnesses of 600-700 Vickers. Controlled production methods and proper heat treatments are essential to ensure correct composition, freedom from residual stresses, dimensional stability and maximum toughness. High abrasion resistance is not necessarily the only criterion for choice of grinding element material, especially when corrosion is present. In such cases, the cost of a corrosion resistant steel would be beneficial, even though it may have reduced abrasion resistance. The use of high chromium, (12-22 per cent) molybdenum steels (C 2·4-3·6%) has been recommended[5], and steels up to 35 per cent Cr are in use for specific applications.

Experimental Results and Observations from Previous Work at BCURA

Tests were conducted using both the roll crusher and the abrasion tester on 34 samples of coal and several samples of mixtures of coal, shale, quartz and other minerals. The ash content of coal tested varied from 1·6 to 88·9 per cent; volatiles (dmmf), 4·3 to 39·2 per cent; and HI, 32 to 112. The major experimental findings are quoted below:

(a) The associated minerals rather than coal substance are responsible for mill wear, due to the differences in hardness and other properties. A study of the relation between

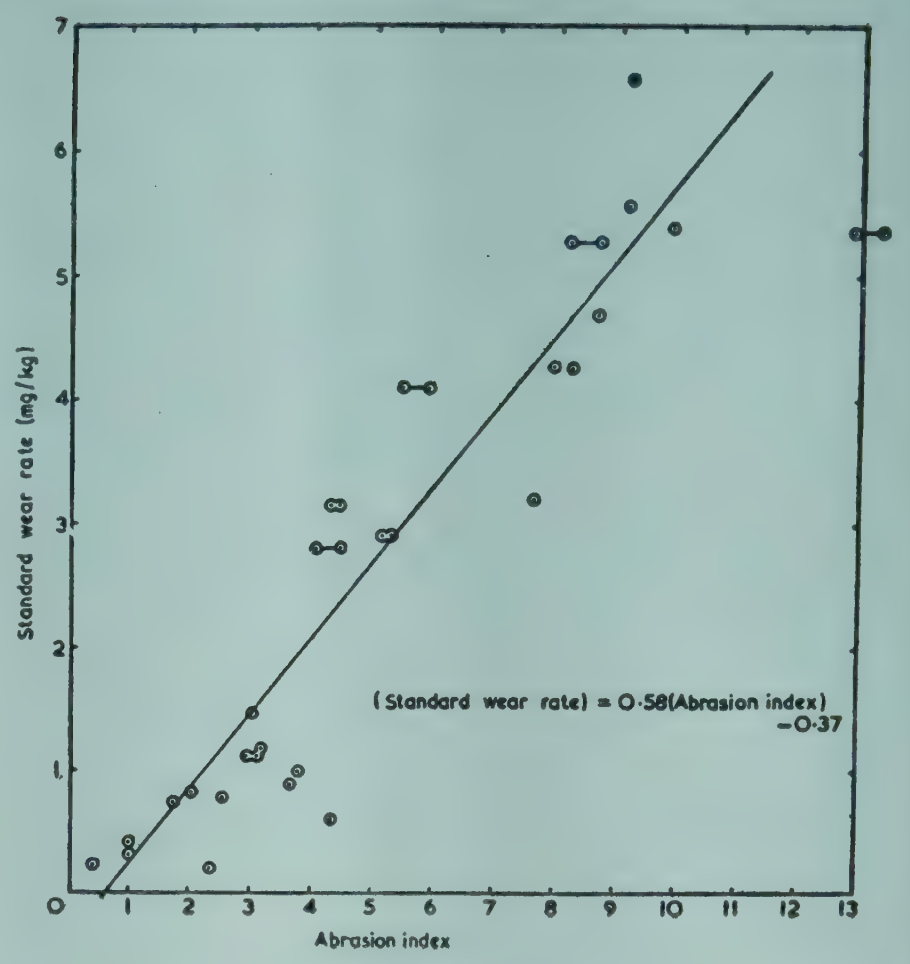


FIG. 5 — RELATION BETWEEN WEAR RATE MEASURED ON ROLL CRUSHER APPARATUS AND ABRASION INDEX

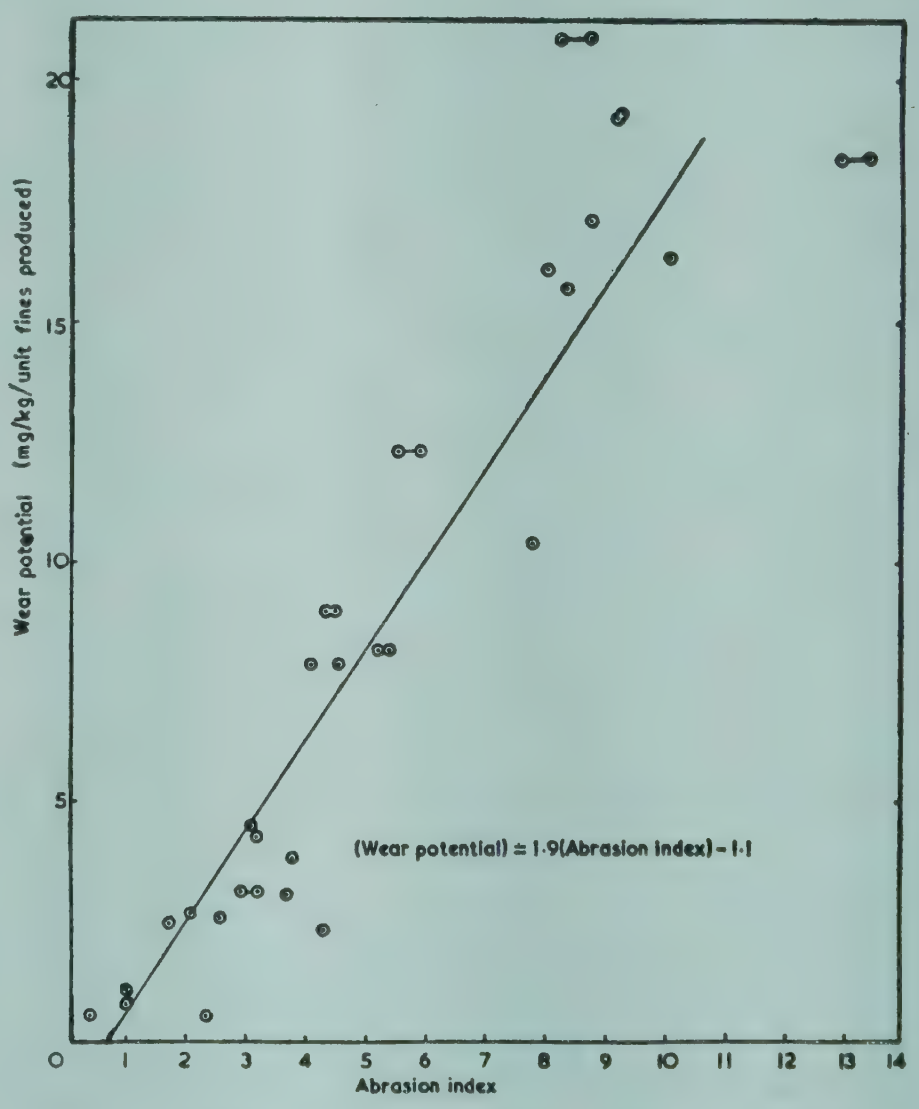


FIG. 6 — RELATION BETWEEN WEAR POTENTIAL MEASURED ON ROLL CRUSHER APPARATUS AND ABRASION INDEX

hardness of major minerals and wear rates was made. It was shown (Fig. 4) that pyrite and quartz with hardnesses higher than that of the grinding element produce excessive wear.

(b) There is a linear relation between abrasion index and standard wear rate or wear potential, the respective scatter-diagrams being shown in Figs. 5 and 6 respectively.

The least squares fits are: $SWR = 0{\cdot}58$ AI-$0{\cdot}37$ and $WP = 1{\cdot}90$ AI-$1{\cdot}1$.

There is a reasonable agreement between the abrasion and roll crusher tests and since the latter simulates a vertical spindle mill, the simple and inexpensive abrasion test may be employed for a rough and ready assessment of the relative abrasiveness of coal. Abrasion index cannot, however, provide any indication of long-term grinding effects on the effects of variation in operating conditions.

It is possible to relate approximately the wear rate of the model to typical full-scale conditions by extrapolation of the results of the roll crusher experiments; this involves relationships between wear rates and (i) applied load, (ii) roll speed, (iii) feed rate, and (iv) width of the gap between rolls.

(c) With increase in percentage of quartz and pyrite, shale and also increase in particle size of quartz, there is a corresponding increase in wear rates[8,9]. The experimental results depicting the relationship are shown in Figs. 7-9.

In a separate study[10] of the relative contribution to wear of different parts of two coal seams, the following relationship was established between wear potential and quartz (Q) and pyrite content (P):

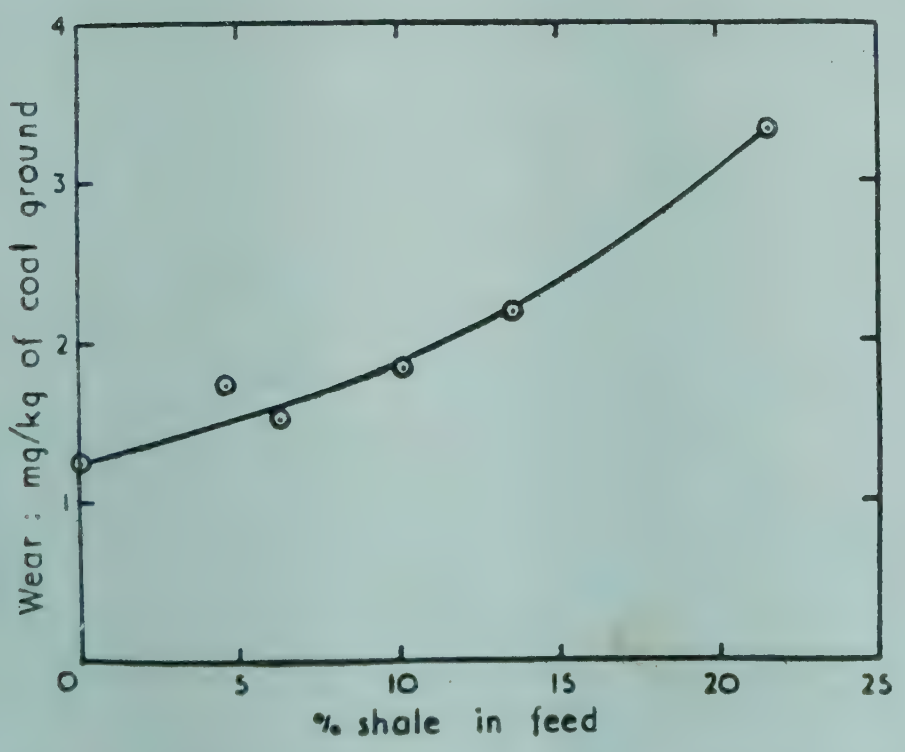


FIG. 7 — RELATION BETWEEN WEAR RATE AND SHALE CONTENT OF FEED

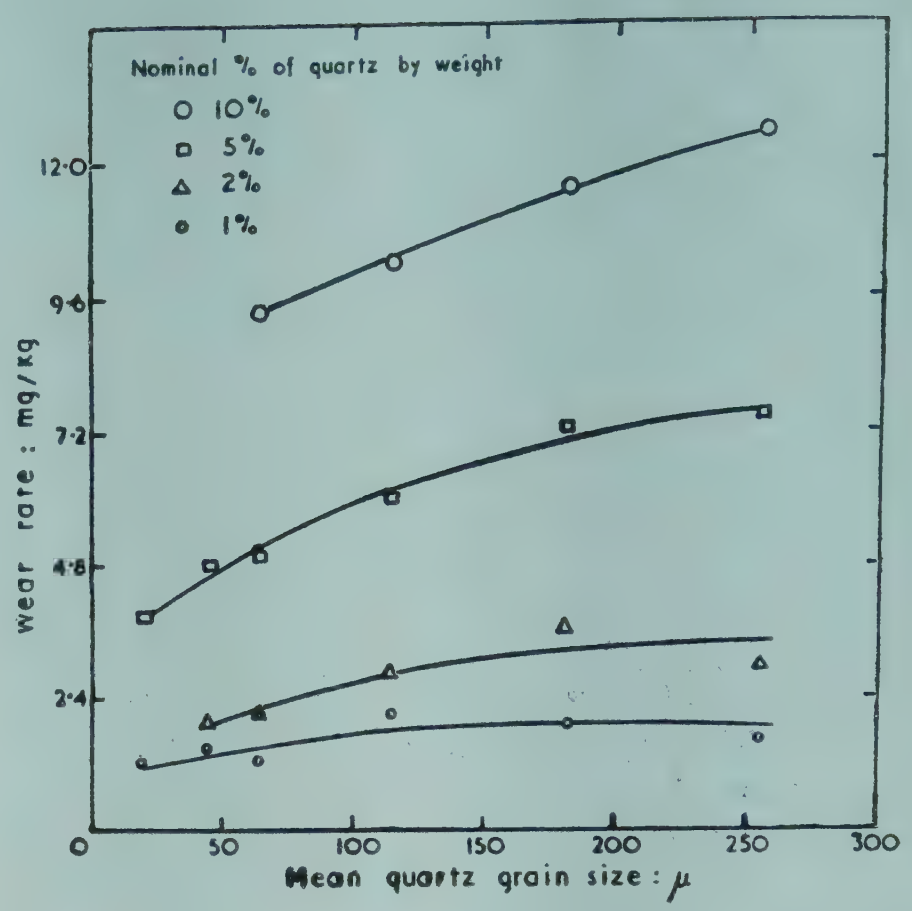


FIG. 8 — DEPENDENCE OF WEAR RATE ON GRAIN SIZE OF QUARTZ ADDITION TO FEED

$$WP = 3{\cdot}16 + 0{\cdot}44Q + 0{\cdot}37P$$

quartz percentages range up to 24 and pyrite to 6·2 per cent.

(d) In a study of the high temperature corrosion mechanism[11] and its effects on the wear of crushers, it was concluded that pyrite in the smaller particle size can cause excessive corrosion and hence increases in wear rate. This is attributed to the exothermic oxidation of pyrite, particularly of smaller particles, the large thermal conductivity causing heat dissipation in larger particles.

(e) A mathematical model of the breakage mechanism in a roll crusher has also been attempted[12].

In using and interpreting the results of these tests, the following points need special consideration: The wear rate is influenced by the way in which the final product is obtained. The wear caused in grinding by a single stage of severe breakage is completely different from that caused by several stages of mild breakage. The operating conditions in a full-scale mill will thus affect wear rate per unit output of fines and the same coal crushed by two different mills may produce different wear effects.

A Factorial Experiment with Abrasion Apparatus

The determination of abrasiveness by Yancey, Geer and Price apparatus is

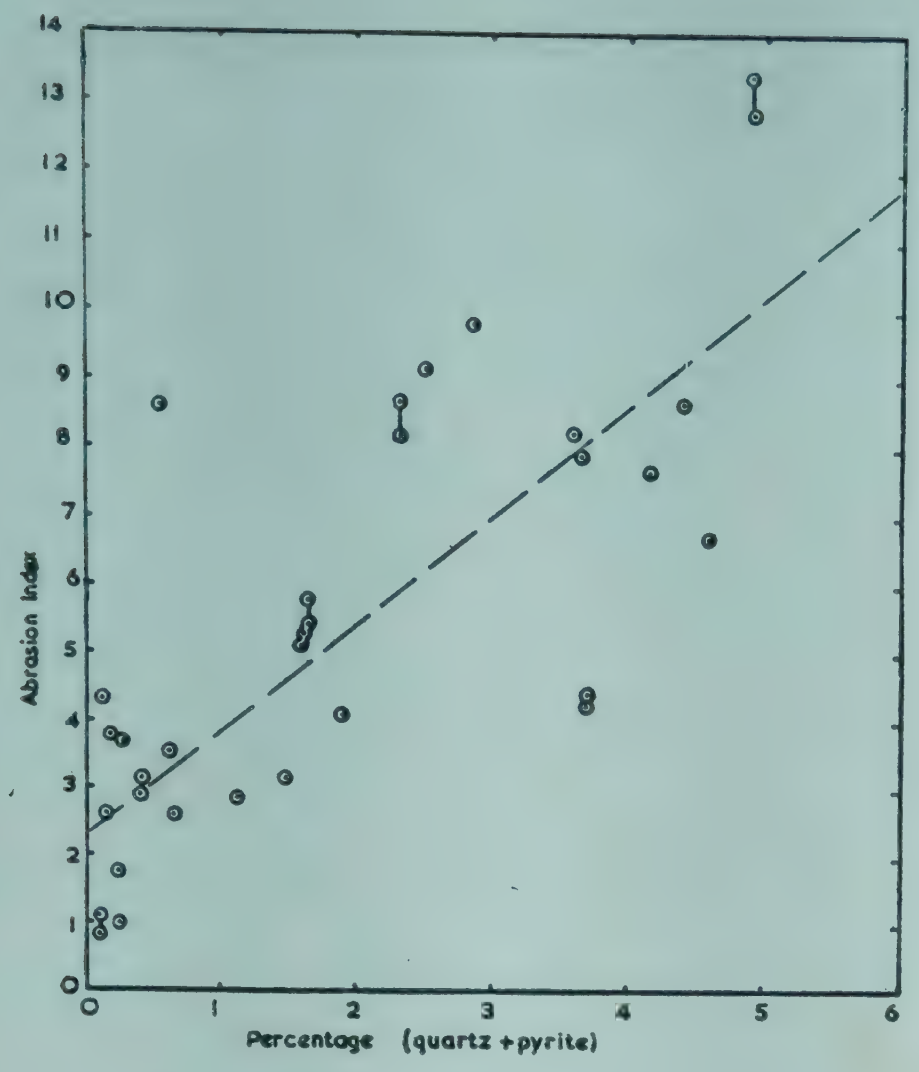


FIG. 9 — EFFECT OF QUARTZ AND PYRITE ON ABRASION INDEX

influenced by many variable factors. The original authors studied effects of feed rate, particle size, hardness of the material for wearing blades, clearance between blades and walls and the bottom of the mortar, etc., on abrasion independent of each other. The statistical design carried out by the present author provides for a study of the effects of the three variables, viz. material and surface conditions and of the wearing blades and also location of the blades simultaneously on the abrasion measurements.

A 2^3 factorial design was used, i.e. each of the three factors was at two levels as shown below:

(i) Wear blades material: (a) soft iron, and (b) mild steel.
(ii) Surface conditions: (a) polished, and (b) roughened.
(iii) Location in respect of wall and bottom of mortar: (a) 0·2 in., and (b) 0·4 in.

The hardness of the soft iron and mild steel polished blades were measured by both the Leitz miniload hardness tester, giving Vickers microhardness, and the Rockwell macrohardness tester. The average Vickers hardness with 200 g load for soft iron was 140 kg/mm² and for mild steel 136 kg/mm² and the average Rockwell hardnesses of 65 and 60 respectively on 160 kg load. The corresponding Rockwell B values of the roughened blades are 63 (soft iron) and 62 (mild steel). The surfaces of one set each of the soft iron and mild steel blades were roughened by No. 3 emery paper for a period of two minutes (one minute each side of the blade). Three coals were selected

TABLE 1 — COAL NO. 1 : NEWDIGATE (HAND PICKED) $\times 10^{-4}$ g

(Time of test: 8 min. 9 sec. to 8 min. 18 sec.)

Type of metal / Location (in.)	Soft iron						Mild Steel					
	Polished			Roughened			Polished			Roughened		
	Blades	I	II	Blades	I	II	Blades	I	II	Blades	I	II
0·2	S_1	11	25	S_5	51	44	M_1	26	28	M_4	50	47
	S_2	13	25	S_6	30	37	M_2	29	22	M	43	28
	S_3	11	19	S_7	35	38	M_3	32	23	M_6	33	50
	S_4	18	5	S_8	13	41	M_8	33	24	M_7	29	51
	Total:	53	74	Total:	129	160	Total:	120	97	Total:	155	176
	Blades	I	II	Blades	I	II	Blades	I	II	Blades	I	II
0·4	S_1	25	28	S_5	12	17	M_1	23	32	M_4	26	20
	S_2	26	30	S_6	10	3	M_2	34	34	M_5	20	24
	S_3	23	16	S_7	8	7	M_3	35	33	M_6	30	22
	S_4	35	19	S_8	6	8	M_8	43	30	M_7	21	18
	Total:	109	93	Total:	36	35	Total:	135	129	Total:	97	84

TABLE 2 — COAL NO. 2: NEW SHELDON LOW MAIN UTS $\times 10^{-4}$ g

Location (in.)	Soft iron						Mild steel					
	Polished			Roughened			Polished			Roughened		
	Blades	I	II	Blades	I	II	Blades	I	II	Blades	I	II
0·2	S_1	548	518	S_5	494	498	M_1	466	470	M_4	368	498
	S_2	740	721	S_6	596	599	M_2	521	539	M_5	445	528
	S_3	217	285	S_7	237	234	M_3	247	272	M_6	331	522
	S_4	300	326	S_8	357	313	M_8	678	679	M_7	520	346
	Total:	1805	1850	Total:	1684	1644	Total:	1912	1960	Total:	1664	1894
	Blades	I	II	Blades	I	II	Blades	I	II	Blades	I	II
0·4	S_1	321	295	S_5	366	299	M_1	275	195	M_4	261	259
	S_2	761	695	S_6	589	650	M_2	609	426	M_5	318	266
	S_3	454	476	S_7	413	526	M_3	591	480	M_6	680	547
	S_4	538	490	S_8	555	570	M_8	700	515	M_7	772	645
	Total:	2074	1956	Total:	1903	2045	Total:	2175	1616	Total:	2031	1717

TABLE 3 — COAL NO. 3: BURDON MILL UTS $\times 10^{-4}$ g

Location (in.)	Soft iron				Mild steel			
	Polished		Roughened		Polished		Roughened	
	Blades	I	Blades	I	Blades	I	Blades	I
0·2	S_1	305	S_5	259	M_1	268	M_4	290
	S_2	348	S_6	278	M_2	267	M_5	162
	S_3	224	S_7	246	M_3	292	M_6	319
	S_4	295	S_8	265	M_8	354	M_8	435
	Total:	1172	Total:	1048	Total:	1181	Total:	1206
	Blades	I	Blades	I*	Blades	I	Blades	I
0·4	S_1	246	S_5	324	M_1	214	M_4	195
	S_2	324	S_6	280	M_2	177	M_5	157
	S_3	223	S_7	327	M_3	193	M_6	241
	S_4	365	S_8	309	M_8	376	M_7	334
	Total:	1158	Total:	1240	Total:	960	Total:	927

*Paddle arm dislocated after 1160 revs.

for the purpose, the proximate analyses of the coals being given below:

Analysis (air dried) %	Coal No. 1 Newdigate hand picked (2-3-1971)	Coal No. 2 New Shildon low main uts (11-3-1971)	Coal No. 3 Burdon mill uts (15-3-1971)
Moisture	10·2	1·9	4·8
Volatile	30·0	32·3	28·4
FC	57·7	50·4	46·5
Ash	2·1	15·4	20·3

Coal No. 1, having a low ash content, is supposed to be only mildly abrasive, whereas coal No. 2 is highly abrasive. The results of the tests are set out in Tables 1-3. Time per test was 8 min. 8 sec. to 8 min. 16 sec. and sample wt 2 kg. Pending a full statistical analysis of the results, it is seen that contrary to expectations, smooth surfaces have been abraded greater with 0·2 in. gap irrespective of the type of metal. With 0·4 in. gap, on the other hand, the results with both polished and roughened surfaces are more or less similar. It is intended to conduct further

experiments with Indian coals before standardization of the method.

Acknowledgement

The work reported here was carried out at BCURA Industrial Laboratories Ltd, Leatherhead, Surrey, the author being aided by a grant under the UK Government Technical Assistance Training Scheme operated by the British Council to whom grateful acknowledgement is made. The author's stay at BCURA Ltd was made possible by the kind permission of the Director, BCURA, and of the Vice-President, Director-General, CSIR, and the Director of CFRI (CSIR) (India), to whom thanks are also due. Grateful thanks are also due to Mr F. J. Hiorns, Superintendent, and other Scientists of the Physics Department for guidance and cooperation.

N. C. SINHA

References

1. YANCEY, H. F., GEER, M. R. & PRICE J. D., *Min. Engng*, **3** (1951), 262.
2. PARISH, B. M. & BEAMAN, A. L., *BCURA Members' Information Circular No.* 311, 1966.
3. HIORNS, F. J. & PARISH, B. M., *BCURA Members' I.C. No.* 297, 1965.
4. GILL, P. F., *BCURA Physics Note No.* 673, 1969.
5. HIORNS, F. J., *Brit. chem. Engng*, **15** (12) (1970), 1565.
6. HIORNS, F. J. & PARISH, B. M., *BCURA Members' I.C. No.* 295, 1965.
7. COOLING, D. R., *BCURA Members' I.C. No.* 296, 1965.
8. COOLING, D. R. & PARISH, B. M., *BCURA Members' I.C. No.* 310, 1966.
9. DIMMOCK, N. A., *BCURA Physics Note No.* 684, 1969.
10. COOLING, D. R., *BCURA Members' I.C. No.* 304, 1966.
11. SHOTTER, J. G., *BCURA Physics Note No.* 624, 1968.
12. LIMB, M. & PARISH, B. M., *BCURA Member I.C. No.* 321, 1967.

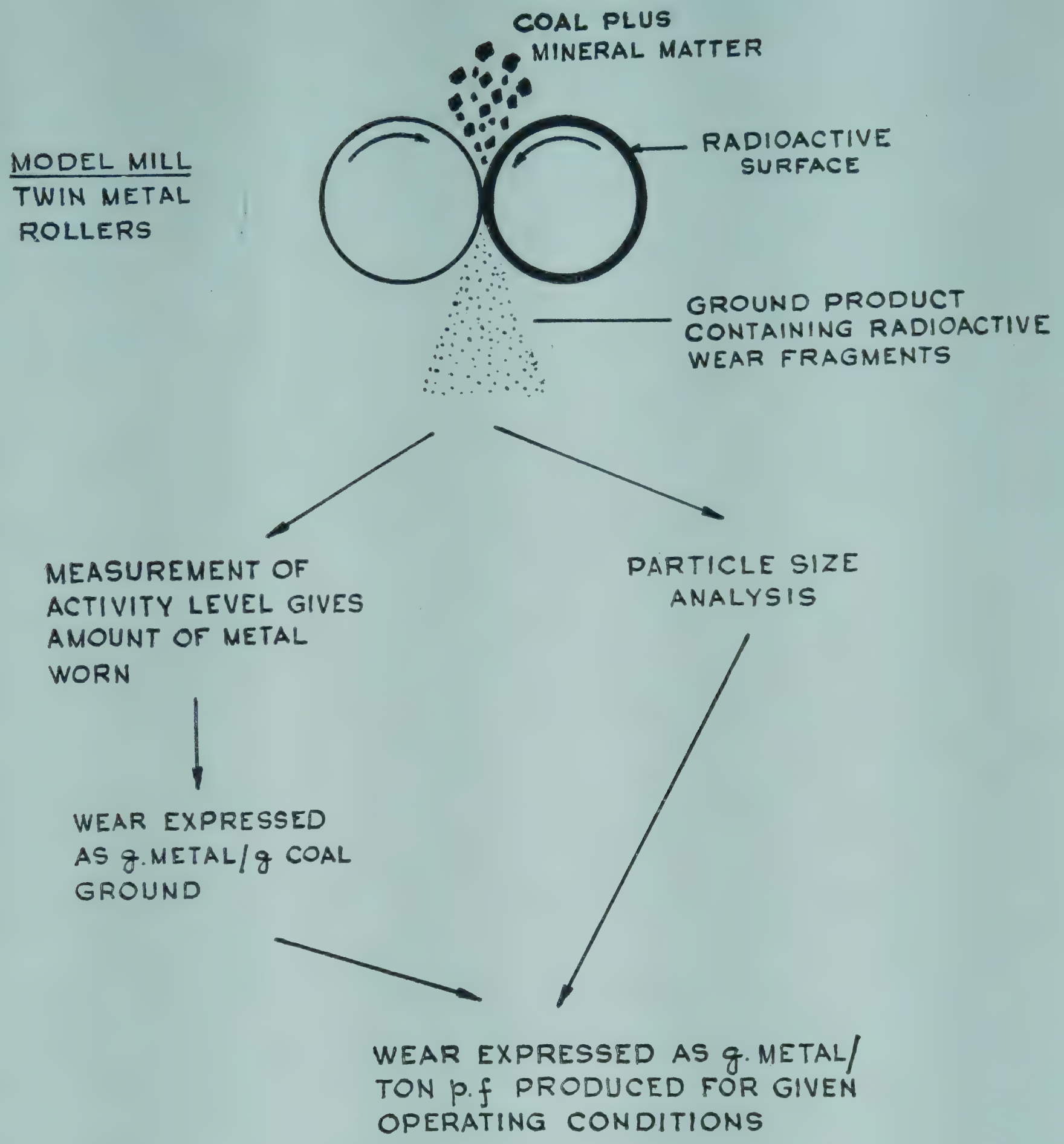
Coal-based Power Stations — *Contd from p.* 73

The post-independence expansion of thermal power generation in India is marked by four distinctive features, viz. (i) an urge for planned and rational utilization of the fuel resources of the country for power generation as a consequence of which it has been made obligatory for all power stations to use the so-called 'byproduct' fuels of coal preparation plants wherever available in the Bengal-Bihar coalfields and to use slack and low grade coals in the outlying fields; (ii) almost exclusive installation of large PF fired boilers incorporating boiler design to permit utilization of low grade fuels with high efficiency and to gain techno-economic advantages of using large sized units with high steam temperature and pressure; (iii) a clear emphasis for locating the power plants in the vicinity of coal preparation plants and pit heads to minimize transport difficulties and to keep freight charge for fuel transportation at its lowest; and (iv) high voltage grids for economic transportation of energy to consumption centres have been developed and inter-connection between hydel and thermal power grids established for appropriate sharing of peak load between the two.

The CFRI studies have shown that the most severe and common problem encountered by a large majority of the power stations is the heavy erosion of different units in the boiler section. Inhomogeneity in coal quality as also inconsistent and sub-standard fuel supply and purchase of coals from numerous small producers or suppliers have often played havoc on the boiler plants. Defects in design of equipment chosen, especially for coal preparation and problem of supply of spares, have added severely to the problem of maintenance of the power plants. Erosion of the various units of the power plant from coal preparation stage to the ID fans has profound influence on the plant utilization capacity. Mineral constituents in the coal and products of imperfect combustion are major causes of erosion. The equipment used for grinding of coal and their performance can be a major cause of erosion.

"Abrasiveness of coal and associated minerals in relation to pulverizer wear", the second article published in this issue of the *News*, incorporates a review of the work done so far and also the results of a study undertaken at BCURA. This is of major importance to the modern power stations using

(*Contd on p.* 114)



ASSESMENT OF WEAR IN COAL PULVERIZER

AN APPRAISAL ON THE QUALITY OF COALS OF KANHAN VALLEY COALFIELD

Introduction

KANHAN valley coalfield is important as it contains sizeable reserves of caking and medium coking coals which are scarce in central, western and southern parts of India. Since 1965, Coal Survey Laboratory, Nagpur, has been carrying out a detailed physical and chemical survey of coals from working collieries of this area. Nagpur laboratory has also conducted a detailed assessment of coals obtained from boreholes drilled in Damua block of NCDC. Coal Survey Laboratory of Bilaspur conducted a rapid physical and chemical survey on coals from some of the collieries of Kanhan valley coalfield. Coal Survey Laboratory, Nagpur, in the current year has taken up a project, which envisages assessment of coals occurring in Kanhan valley areas and projection of the data in maps so that they may be useful for the work of the proposed Steel Plant at Hospet.

In this appraisal, an assessment of the quality of coals of III seam (workable section), which is the most important seam of the area and suitable for exploitation, has been discussed.

Location

The Kanhan valley coalfield forms a continuous coal-bearing tract with Pench valley coalfield in east and upper Tawa valley coalfield in the west. There is no sharp demarcation between the boundaries of these coalfields which are collectively known as Pench-Kanhan-Tawa valley coalfield. The nearest railway station of the area is Hirdagarh, situated towards the south of the coalfield. Parasia railway station is situated towards the east. Besides, there is a motorable road connecting Kanhan valley with Parasia and Chhindwara.

Geology

The general geological sequence of Kanhan valley area (after GSI) is as follows:

Alluvium	Recent
Deccan trap	Upper Cretaceous
Infra-trappeans (Jabalpur stage ?)	Upper Gondwana
Motur stage Barakar stage (coal bearing) Talcher series	Lower Gondwanas
Archaean	

Coal seams are restricted within Barakars at a depth of about 30-47 metres from the base of the Moturs. The general strike of the strata is ENE-WSW with dips normally varying between 5° and 15° towards north. The area is very much disturbed by severe faulting. Owing to the frequent presence of strike faults, sometimes forming graben structure, the directions of strike and amount of dips have changed. Presence of igneous intrusions have also been observed sometimes adversely affecting the coal seams.

Coal Seams

Coal seams occurring in Kanhan valley area are exploited at Rakhikol, Kalichhapar, Damua, Ghorawari, Kalan and Ghorawari-Hirdagarh collieries (Fig. 1). Apart from the working collieries, the area situated towards the north of Kalichhapar and Damua collieries, known as Damua block of NCDC, has been prospected in detail by drilling by NCDC, GSI and IBM. A statement showing the details of seams, thickness, working section, parting, etc., of the collieries and prospecting block has been shown in Table 1.

From the information collected from the collieries and reports of GSI, IBM, and NCDC, it appears that there is an important seam, termed III seam by IBM/NCDC (locally known as I seam or main seam, termed by GSI also as I seam) which is the topmost seam of the area, apparently occurring throughout the extension of Kanhan valley and also continuing in Pench valley in the east and Upper Tawa valley in the west.

All the collieries of Kanhan valley area are exploiting this seam because of its greater thickness throughout the field. The full thickness of III seam has been reported to vary between 2·7 and 6 metres

PLATE NO:-

GEOLOGICAL SKETCH MAP OF KANHAN VALLEY COALFIELD

SHOWING LOCATION OF COLLIERIES & DAMUA BLOCK ALONG WITH SAMPLING POINTS AND SOME PHYSICAL & CHEMICAL PROPERTIES OF COALS OF III SEAM

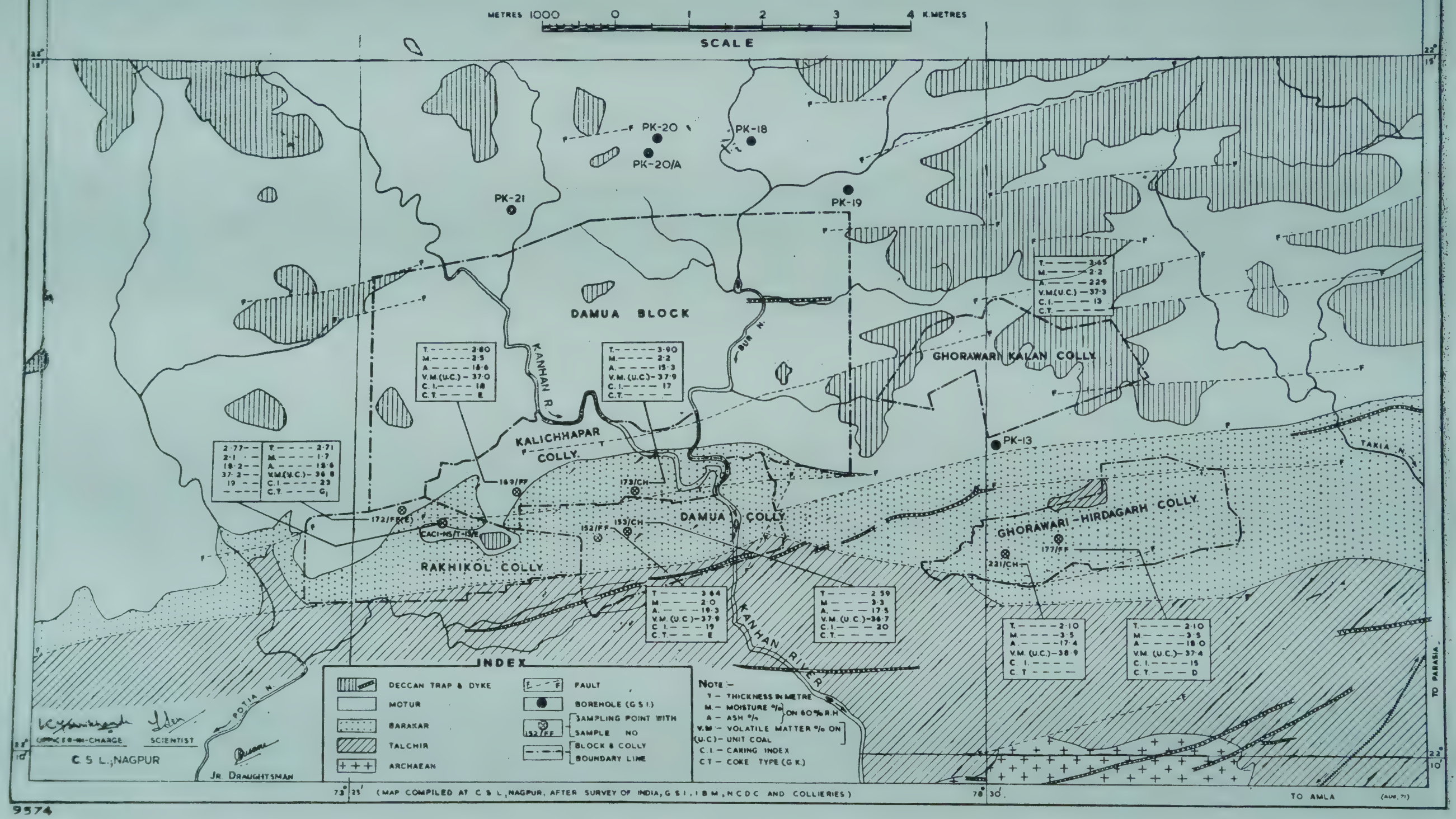

METRES 1000 0 1 2 3 4 K.METRES
SCALE
78° 25'
78° 30'
22° 15'
22° 10'
PK-20
PK-20/A
PK-18
PK-21
PK-19
DAMUA BLOCK
KANHAN R.
BUR N.
KALICHHAPAR COLLY.
GHORAWARI KALAN COLLY
PK-13
TAKLA N.
DAMUA COLLY
GHORAWARI-HIRDAGARH COLLY
RAKHIKOL COLLY
KANHAN RIVER
POTIA N.
TO PARASIA
TO AMLA
169/FF
173/CH
172/FF(E)
CACI-105/T-13/E
152/FF
153/CH
177/FF
221/CH
T - - - - 2·80
M - - - - 2·5
A - - - - 16·6
V.M.(U.C.) - 37·0
C.I. - - - - 18
C.T. - - - - E
T - - - - 3·90
M - - - - 2·2
A - - - - 15·3
V.M. (U.C.) - 37·9
C.I. - - - - 17
C.T. - - - - —
T - - - - 3·45
M - - - - 2·2
A - - - - 22·9
V.M.(U.C.) - 37·3
C.I. - - - - 13
C.T. - - - - —
2·77 - - T - - - - 2·71
2·1 - - M - - - - 1·7
18·2 - - A - - - - 18·6
37·2 - - V.M.(U.C.) - 36·8
19 - - - C.I. - - - - 23
- - - - - C.T. - - - - G1
T - - - - 3·64
M - - - - 2·0
A - - - - 19·3
V.M. (U.C.) - 37·9
C.I. - - - - 19
C.T. - - - - E
T - - - - 2·59
M - - - - 3·3
A - - - - 17·5
V.M. (U.C.) - 36·7
C.I. - - - - 20
C.T. - - - - —
T - - - - 2·10
M - - - - 3·5
A - - - - 17·4
V.M. (U.C.) - 38·9
C.I. - - - - —
C.T. - - - - —
T - - - - 2·10
M - - - - 3·5
A - - - - 18·0
V.M. (U.C.) - 37·4
C.I. - - - - 15
C.T. - - - - D
INDEX
DECCAN TRAP & DYKE
MOTUR
BARAKAR
TALCHIR
ARCHAEAN
FAULT
BOREHOLE (G.S.I.)
SAMPLING POINT WITH SAMPLE NO
BLOCK & COLLY BOUNDARY LINE
NOTE –
T – THICKNESS IN METRE
M – MOISTURE % ON 60% R.H
A – ASH %
V.M – VOLATILE MATTER % ON (U.C.) – UNIT COAL
C.I. – CAKING INDEX
C.T – COKE TYPE (G.K.)
OFFICER-IN-CHARGE
SCIENTIST
C.S.L., NAGPUR
JR. DRAUGHTSMAN
(MAP COMPILED AT C.S.L., NAGPUR, AFTER SURVEY OF INDIA, G.S.I., I.B.M., N.C.D.C. AND COLLIERIES)
(AUG. 71)
9574

FIG. 1 — GEOLOGICAL SKETCH MAP OF KANHAN VALLEY COALFIELD

TABLE 1 — STATEMENT SHOWING THICKNESS OF SEAM, PARTINGS, WORKING SECTIONS, ETC., OF SEAMS OF KANHAN VALLEY COALFIELD

Sl No.	Colliery	Owner	Thickness of seam and partings	Working section	Remarks
1	Rakhikol	S.C. Khambatta & Co., Bombay	III (locally main) 2·7-3·0 m	Full section	Physical and chemical survey conducted by CSL in respect of working section
2	Kalichhapar	M/s C.P. Syndicate Pvt. Ltd.	III (locally main seam) 5·9 m; parting, 8 m; II (local bottom seam), 1·2 m	Bot. sec.	do
3	Damua	Kanhan Valley Coal Co. Ltd.	III (local main seam), 5·9 m; parting, 7·2 m;	Bot. 3·6-4·5 m	do
			II (local bottom seam), 1·0-1·2 m	Not being worked	
4	Ghorawari-Kalan	T. K. Shukla	III (locally 1 seam), 5·2 m; parting, 21·3 m	Bot. sec.	do
			II (locally 2 seam), 1·5 m	Not being worked	
5	Ghorawari-Hirdagarh	T. A. Trivedi Bros, Chhindwara	III (locally 1 seam), 4-4·2 m; parting, 4·5-8·0 m	Bot. sec. (2·1-2·2 m)	do
			II (locally 2 seam), 1·2-1·3 m	Full sec.	do
6	Damua block	NCDC	Seam III, top sec., 3·0-4·0 m; parting, 0·00-8·73 m (increasing towards east);	Workable	Borehole investigation conducted at CSL
			Seam III, bottom sec., 0·80-1·00 m; parting, 3·4-9·3 m	Not workable	
			Seam II, 0·6-0·8 m; parting, 3·4-7·9 m	do	
			Seam I, 0·08-1·0 m; parting, 2·37-8·58 m	do	
			Lower coal band, 0·03-0·31 m	do	
7	PK-13 (GSI) (Ghorawari-Kalan)		Seam III top, 4·70 m; parting, 3·50 m		do
			Seam III bot., 1·00 m; parting, 14·46 m		
			Seam II, 1·20 m; parting, 24·65 m		
			Seam I, 0·40 m		

in the collieries where its lower section is usually worked. Apart from seam No. III, another seam known as II seam whose quality is shown in Table 2 (locally II, bottom seam and at Ghorawari-Hirdagarh colliery as Bootodas seam) has been reported in the working collieries after a parting of about 7 to more than 20 metres from III seam. The thickness of this seam is less (1-1·5 m) and is being worked only at Ghorawari-Hirdagarh colliery. Although no information regarding the occurrence of any seam below seam II in the working colliery is available from the colliery authorities, a seam of thickness 0·40 m which may be correlated as No. I seam has been encountered after a parting of about 25 m below No. II seam in borehole No. Pk-13 which is located in the leasehold area of Ghorawari-Kalan colliery.

In Damua block, detailed exploration carried out by IBM, NCDC and GSI has proved the existence of 3 seams out of which top section of the topmost seam (III seam after IBM/NCDC) is attractive owing to its greater thickness developed throughout the block. III seam has been found to be split in greater part of the block, although towards the eastern part of the block around BH No. PK-14, the seam appears to have

Colliery	Seam/sections (thickness)	CV (kcal/kg)	CI	HGI
Rakhikol	III, full thickness (	6755 (8680)	23	—
	do	6670* (8670)	22	—
	III (2·77 m)	6690 (8590)	19	53
	do	6670 (8620)	—	51
Kalichhapar	III, bot. sec. (2·80	6665 (8495)	18	53
	do	6625 (8415)	17	—
	III, bot. sec. (3·90	6810 (8470)	17	—
	III, working sec. (	6705 (8500)	15	51
	do	6605 (8480)	—	53
Damua	III, bot. sec. (3·64	6535 (8575)	19	55
	do	6430* (8440)	—	—
	III, bottom sec. (2·	6590 (8510)	20	59
Ghorawari-Kalan	III, bottom sec. (3 workable sec.	6185 (8515)	13	46
Ghorawari-Hirdagarh	III, bottom sec. (2	6350 (8280)	15	49
	III, bottom sec. (2	6475 (8355)	—	—
	II, full sec. (1·2 m	6340 (8390)	13	—
	II, full sec. (1·2 m	6480 (8400)	15	—

coalesced. The thickness of parting between top and bottom sections of III seam which comprises a few thin coaly layers gradually increases towards the north-east corner of the block where the thickness has been recorded to be of the order of 4-8 metres. The parting between top and bottom sections of III seam generally increases towards the dip side. While the top section of III seam has developed workable section in major part of the block, the thickness of bottom section is usually less than 1 metre in most of the area. The parting between III bottom and II seam and that between II seam and I seam usually range between 4·50 and 6·90 metres and 3·4 and 7·9 m respectively. Both the seams are not attractive for exploitation owing to low thickness.

Physical and Chemical Properties of Coals of III Seam (Workable Section) in Working Collieries

Details of chemical analyses of coals from working section of collieries have been presented in Table 2.

In most of the areas of working collieries, the quality of coal of working section of III seam (bottom section) has been found to be fairly good with moisture and ash varying between 1·7 and 3·5 per cent and 15·3 and 19·3 per cent respectively. Towards the eastern part in the dip side in Ghorawari-Kalan colliery, the quality of coal of working section records higher ash content (22·9 per cent). BH No. PK-13, located in this region, records about 28 per cent ash for coals of III seam (top section). The unit coal volatile matter of the coals of working section (III seam) of collieries usually ranges between 36·7 and 37·9 per cent except in one sample from Ghorawari-Kalan colliery where the volatile matter content has been found to be of higher order (38·9 per cent on unit coal basis). Unit coal carbon and hydrogen of coals of III seam (bottom section) range normally between 84·6 and 87·2 per cent and 5·16 and 5·57 per cent respectively. The carbon content is higher in coals of western part of the field suggesting a higher order of maturity. Caking index has also been found to be of the order of 13-15. Calorific value and HGI of coals of working section range between 6185 and 6755 kcal/kg (unit coal 8280-8680 kcal/kg), and 46 and 59 respectively. Sulphur (total) content of these coals usually vary between 0·43 and 1·04 per cent (mostly less than 0·90 per cent), whereas phosphorus content has been recorded to vary between 0·008 and 0·078 per cent. Foot-by-foot samples of coals collected from the working collieries reveal that in most of the collieries, coals of about 2-2·5 m section of III seam from floor (except the basal section of Ghorawari-Hirdagarh colliery), is in general of better quality with less than 20 per cent ash on dry basis. In the present working section, a band usually of 0·10 m or less in thickness has been recorded at certain places. On inclusion of the band, the ash content of coal increases by about 0·6-1·3 units.

Low Temperature Carbonization at 600°C

The low temperature Gray-King assay results of coal of working section of the collieries have been presented in Table 3.

The study reveals that the yield of tar is quite high in all the coals tested. Coke type D to G_1 indicates fairly strong caking nature of these coals, even when the ash content (dry) varies between 17·1 and 19·7 per cent. The coals of Rakhikol colliery, situated towards the western part of the field, shows coke pencil of G_1 type indicating general increase in caking properties towards the western part of the field.

Physical and Chemical Properties of Coals of III Seam, Top Section (Workable Section) of Damua Block

The coals of III seam top section are attractive for exploitation owing to their greater thickness and quality in Damua block. Correlation between the workable section of III seam of Damua block and the working section of III seam of other collieries has not yet been established for want of data from boreholes and chemical and lithological data from full thickness of III seam of colliery area.

In the present article, the ranges of analytical data in respect of Damua block have been presented in Table 4.

Although 4 persistent seams/sections have been found to occur in Damua block, coals of top section of III seam is attractive owing to its greater thickness and good

TABLE 3

Colliery	Ash % (dry basis)	Calculated yield per tonne of dry coal					Coke type
		Coke (kg)	Tar (lit.)	Liquor (lit.)	Ammonia (kg)	Gas (cu m) at 60°F and 30 in. saturated pressure	
Rakhikol	18·9	769·5	120·0	40·0	1·2	99·2	G_1
Kalichhapar	17·1	764·0	120·5	45·0	1·2	99·6	E
Damua	19·7	764·5	133·5	40·0	1·2	100·8	E
Ghorawari-Hirdagarh	18·7	753·5	125·5	46·0	1·2	99·8	D

TABLE 4 — STATEMENT SHOWING RANGE OF VARIATION OF SOME CHEMICAL AND PHYSICAL PROPERTIES OF COALS OF III SEAM (TOP SECTION), DAMUA BLOCK

Thickness (m)	At 60% RH basis				Phosphorus %	On DMF basis				
	Moist. %	Ash %	CV kcal/kg	Total S%		CV kcal/kg	VM %	C %	H %	CI
Range 1·2-5·1	1·7-3·8	16·1-25·5	5885-6875	0·3-0·9	0·011-0·088	8250-8655	30·0-37·9	84·8-88·5	5·1-5·7	9-20
Average variation 2·6-4·6	1·7-3·0	17·3-22·0	6295-6555	0·3-0·9	0·011-0·088	8360-5835	34·1-37·0	85·6-87·7	5·2-5·5	11-19

TABLE 5 — GRAY-KING LTC ASSAY, SEAM III TOP SECTION

Yield per tonne of dry coal						Coke type
Ash (dry)	Coke (kg)	Tar (lit.)	Liquor (lit.)	Ammonia (kg)	Gas at STP (sat.) cu. m.	
16·3-23·0	746·0-785·0	99·5-127·0	40·0-57·5	0·8-1·8	91·0-106·5	C-F

quality. The moisture and ash contents (on 60 per cent RH and 40°C basis) vary usually between 1·7-3·0 and 17·3-22·0 per cent respectively, although at certain places (particularly towards the eastern part), the coals of seam III (top section) has been found to be either affected by igneous intrusion and/or of inferior quality (shaly). The unit coal volatile matter, carbon and hydrogen contents normally range between 34·1 and 37·0, 85·6 and 87·1 and 5·2 and 5·5 per cent respectively. Usually, one or more dirt bands have been encountered within the workable section (top section) of III seam and on inclusion of these bands, the ash content increases from 18·4 to about 30 per cent. Total sulphur and phosphorus contents in coals of III top seam have been found to range between 0·3-0·9 and 0·011-0·088 per cent respectively. Caking index of these coals normally range between 11 and 19, while HGI determined on 3 samples shows figures around 50. The properties of coals have been found to be adversely affected by igneous intrusions at many places.

Results of low temperature Gray-King assay of coals of III seam (top section) has been presented in Table 5.

The assay of unaffected coals shows that these coals yield substantial amount of tar.

The properties of normal coals of seam III, top section of Damua block appears to be similar to those of working colliery in many

respects. However, the coals of Rakhikol area which records coke pencil of G_1 type appears to be superior amongst the coals of Kanhan valley area so far tested.

Recommendations

In view of strongly caking properties and low ash content of these coals, it may be recommended to drill a few boreholes of larger diameter in Damua block to obtain samples suitable for special carbonization tests including box coking test and also for small-scale washability tests. These boreholes should be put down towards the north-central and western parts of the Damua block where III seam (top section) appears to be free from igneous intrusions. It may further be recommended to explore the areas situated towards the west of Damua block by drilling for ascertaining the continuity of III seam and to study its properties.

Acknowledgement

The authors are grateful to the Director, Central Fuel Research Institute, for his kind permission to publish this paper. They are also grateful to the Deputy Director (CS) and the Asstt. Director (CS) for their kind help in the finalization of the same.

S. Sen, S. M. Singh, B. A. Samannu

B. D. Majumdar, R. N. Kudwalli &
K. Y. Shrikhande

Bibliography

1. *Annual Report*, 1957, Regional Coal Survey Station, Bilaspur.
2. *Annual Report*, 1964, Regional Coal Survey Station, Nagpur.
3. *Annual Reports*, 1965, 1966, 1967, 1968 and 1969, Coal Survey Laboratory, Nagpur.
4. *Technical Report No.* 6, *Damua Colliery, Pench-Kanhan Coalfield*, 1965, Coal Survey Laboratory, Nagpur.
5. *Tech. Report No.* N/1/66, *Kalichhapar Colliery, Pench-Kanhan Valley Coalfield*, 1966, Coal Survey Laboratory, Nagpur.
6. *Tech. Report No.* N/2/66, *Rakhikol Colliery, Pench-Kanhan Valley Coalfield*, 1966, Coal Survey Laboratory. Nagpur.
7. *Tech. Report No.* N/2/67, *Ghorawari-Hirdagarh Colliery, Pench-Kanhan Valley Coalfield*, 1967, Coal Survey Laboratory, Nagpur.
8. *Tech. Report No.* N/14/65 and N/6/66, *Damua Bloch, Pench-Kanhan Valley Coalfield*, 1965-66, Coal Survey Laboratory, Nagpur.
9. Chandra, T. K. & Ghosh, P. K., *A Report on the Geology and Coal Resources of the Pench-Kanhan Valley Coalfield, Dist. Chhindwara (M.P.)*, April 1960, Geological Survey of India.
10. Hunday, A., Hanumantha Rao, V. V. S. R. & Suryanarayanan, M., *Report on the Detailed Exploration for Coal in the Pench-Kanhan Coalfield, M.P.*, May 1964, Indian Bureau of Mines.
11. Chandra, T. K., Choudhury, K. K. & Shingte, S. K., *Geological Report on Damua Block, Pench-Kanhan Valley Coalfield, Dist. Chhindwara, M.P.*, August 1966, NCDC.

Spotlight

ON SCIENTIFIC ACTIVITIES

Feasibility Study on the Utilization of Kutkona Coals of M.P.

The baneful effect of using wood and cowdung for domestic heating on soil erosion and agricultural productivity and the need of replacing them by processed smokeless solid fuel have been voiced many a time. Apart from the costly project based on lignite at Neyveli, no large-scale commercial plant has yet come up for making domestic fuel. There are two pilot plants, one at CFRI and another at RRL, Hyderabad. A small commercial plant of 20 t/d capacity based on a CFRI process is functioning at Hyderabad. The areas adjoining south Bihar which is the only source of coking coal, use 'bhatta' coke which is of indifferent quality. Besides this, inadequate railway haulage and excess freight charge have stood in the way of its greater use in other areas. Further, the non-availability of coking coals in M.P. is a hindrance to the increasing development of metallurgical industry.

Extensive laboratory and pilot plant tests carried out at CFRI with semi-coking coals of Sohagpur-Jhilmili belt of M.P. have established that excellent domestic and industrial cokes can be made from the sized coals by LTC and from the fines by fluid bed carbonization followed by formed coke process.

Considering all technological and economic factors, an integrated project for utilization of the entire run-of-mine production (1500 t/d) of coals from the Kutkona block of the NCDC is proposed, the lump coals being carbonized in vertical retorts and small coals used for formed coke making. The combined tar will be treated for recovery of phenols and floatation and creosote oils and binders. Production of electrode binders may also be possible but requires further studies. With doubled production in the second phase (which must be preceded by commercial scale tests), extraction of iron with formed coke can also be undertaken in blast furnaces. The retort gases can then be used for synthesis of chemicals or fertilizers.

In the first phase, approximately 420 tonnes of low temperature carbonization coke and 516 tonnes of formed coke for domestic use, 123 tonnes of ferro-alloy grade coke (or 120 tonnes of calcined formed coke), about 6 tonnes of phenolics, about 15 tonnes of floatation grade oil and approximately 16 tonnes of creosote grade oil will be produced daily. The project is estimated to cost about 7·3 crores as on-site investment and approximately 1·45 crores for off-site investment. The ex-plant production cost, before profits on equity capital and taxes, works out approximately to Rs 59 per tonne of which the off-site investment cost accounts for nearly Rs 3·75 per tonne.

The products will find market not only in the major urban and industrial areas of M.P. but also far beyond, perhaps up to Delhi, Hyderabad and Bombay. Calculations of sale values of products show that the smokeless fuel produced can be sold, with handsome profits, at distances up to 1000 km, from the colliery and perhaps as far as 1500 km. The arbitrarily assigned maximum cost of Rs 150 tonne will enable selling the coke to consumers at a distance of 1500 km reckoned on 10 per cent escalation in capital costs and 30 per cent return on equity capital (before taxes).

The project, apart from being economic, may be a pioneering venture not only in diversifying the use of non-coking coals but also may solve major problems for future development of non-coking coals by utilizing the small coals (slack) and coal fines which today constitute a major bottleneck for development of the coal resources of central India. [Based on a Report "A Feasibility Study on the Utilization of Kutkona Coals", prepared by CFRI.]

Production of Anthraquinone from Anthracene

The present annual production of anthraquinone, a basic raw material for the manufacture of dyestuff in the country, is about 2000 tonnes. Considering the growing internal demand and foreign exchange earning potentiality of the material, licences have already been issued for a further production of 2800 tonnes of anthraquinone per annum.

The method for the manufacture of anthraquinone as adopted in the country is through benzene and phthalic anhydride route. The production of phthalic anhydride falls far short of the existing demand and the process is complicated. In order to avoid phthalic anhydride as raw material for anthraquinone and to utilize anthracene which has no demand as such but is available in appreciable quantities as anthracene cake (a byproduct of coal carbonization), CFRI has developed a catalytic oxidation process for converting anthracene to anthraquinone.

The process consists of three major steps: (i) purification of crude anthracene cake, (ii) catalytic oxidation of anthracene, and (iii) purification of crude anthraquinone.

Crude anthracene cake (containing 18-20 per cent anthracene) is upgraded by dissolution and crystallization from selective solvents. Arosolv-acetic acid mixture was found to yield anthracene of 85-86 per cent purity with a recovery around 90 per cent by a single crystallization step. A second crystallization of the above product from the same solvent mixture raised the purity level to 95-96 per cent with the same recovery. Reuse of mother liquor and washings effected a considerable reduction in the solvent feed ratio (from around 4·35 to 1·95) and increase in the recovery of anthracene to around 91 per cent with purity level of more than 90 per cent.

The purified anthracene is then catalytically oxidized in a static or a moving or a fluid bed. The catalyst originally prepared has been improved upon.

The existing pilot plant at the Institute employs the fluid bed process where anthracene vapour mixed with excess hot air is passed through the reactor containing the catalyst in a fluid state and maintained at 400°C. The product vapours and gases pass through the catalyst filter before condensing. The product collected is of 95-97 per cent purity.

The main impurities at this stage are phthalic anhydride and unconverted anthracene. They are removed by washing the product with water and toluene respectively when as pure as 99 per cent anthraquinone is obtained.

The process is covered by Indian Pat. No. 66293. CFRI has entered into a development contact with a chemical engineering consulting firm of Bombay for commercializing the process. [Based on a paper by C. S. B. Nair and D. K. Sen, presented to the CFRI Symposium on Chemicals and Oil from Coal and a note by M. Chakravarty.]

Rapid NMR Method of Estimation of Water

Most organic reactions, especially active hydrogen condensations and catalytic oxidation reactions, result in the formation of water as byproduct. Accurate estimation of this water, an important parameter for determining the reaction mechanism, thereby leading to a better control of the parameters of the desired reaction, is surprisingly difficult, especially when the reaction products are admixed with water-soluble hydrocarbons and water-dissolving systems like ketones, heterocyclic oxygen and/or nitrogen containing organic systems.

An accurate method was sought for at the Institute for estimating water formed during oxidation of toluene, ammoxidation of methyl pyridines and Fischer-Tropsch synthesis which are a few of the important projects being investigated at CFRI.

Of the physical methods available, mass spectrometric method is likely to yield erroneous results due to the hindrance of other radicals, particularly if the resolution power of the instrument is low. Moreover, it is a destructive method. Infrared technique using rock salt accessories has grave limitations. Gas chromatography using special columns can be adopted but the process is almost a destructive one and the dilution of sample vapour by the carrier gas and collection of sample present great difficulties. Hence a non-destructive, quick and accurate method based on high resolution NMR technique was taken up for development.

The variation in chemical shift of hydrogen-bonding proton signals is well known in high resolution nuclear magnetic resonance studies. The variation due to intermolecular hydrogen bonding is of interest because of its concentration dependence even in some non-hydrogen bonding solvents. Based on

the alove, a rapid method has been developed for the estimation of water in complex organic solutions using the NMR technique, the minimum estimable concentration is 1·6 per cent w/w. Accuracy of the method is ±4 per cent. The method has been successfully applied to the estimation of water in a seven-component synthetic test mixture and to the ammoxidation products of beta and gamma-picolines and oxidation products of toluene [unpublished work].

Phase Boundary Determination

Precise detection of the phase boundary between two liquids is often required in the chemical industry. It becomes a problem when the liquids are dark, as in the processing of coal tar and petroleum fractions. In the extraction of coal tar acids and bases, the extracts are usually deep and often there is no noticeable difference in colour between the extract and the raffinate. The separation of such extracts is usually done by visual observation and hence a laborious and at times an inaccurate job. Other devices, though there are, do not give satisfactory results.

While carrying out investigations on extraction and further processing of tar acids and bases at Central Fuel Research Institute, the necessity of a precise instrument was felt and attention was devoted to the development of an efficient detection device. The device now developed is based on the differences in the electrical conductivities of liquids at different electrical potentials. For example, tar oils do not have noticeable electrical conductivities up to 220 volts, whereas solutions of alkalies and acids have marked conductivities in this range of voltage.

In the construction of the instrument, two electrodes are attached to the lower end of an 1 in. diameter glass tube and the other ends of the electrodes lead to a 220 V a.c. mains through a voltage regulator. One electric bulb is included in the circuit in series. During actual experiment, the tube is immersed in the experimental liquid mixture. When it contacts the liquid layer of higher conductivity, a current passes through the circuit and is indicated by the glow of the bulb.

The voltage necessary for sending an appreciable current through the circuit under a particular set of conditions depends on a number of factors, particularly the nature of the liquid used, and is to be determined by preliminary trials. The minimum voltage necessary in the extraction of tar acids and tar bases from tar fractions is 30 V.

The distance between the electrodes is also critical, particularly in the case of tar fractions which give rise to froth or emulsions during extractions. Usually, an 1 in. gap is found to be sufficient for the systems commonly encountered in coal tar processing.

The device can operate with both a.c. and d.c., but d.c. has some disadvantages. In the latter case, polarization takes place which causes drop in current flow. There is risk of explosion also due to the accumulation of hydrogen and oxygen formed by electrolysis when the instrument is left in the liquid system for a longer period. A.C. has no such ill effects.

D.C. supply could, however, be used in conjunction with a multivibrator and an amplifier system. The system works on 3-6 V d.c. supplied by 2 torch cells. The current passes through a multivibrator and the output impulses are fed to one of the electrodes through shielded wires. The other electrode is connected to an amplifier and a loudspeaker. The electrical impulses passing through the circuit (signal) are amplified and produce a distinctly audible sound, the volume of which could be easily regulated This system has the advantage of working with low voltage and is, therefore, safe to use The sound produced is distinct and enables a liquid layer to be pin-pointed quite effectively.

The device could also be modified for maintaining a constant phase boundary between two liquids in a reaction vessel, such as in an extraction column. The electrodes in such cases may be kept fixed and the current generated in the circuit by contacting the conducting phase, made to operate one or more valves which control the liquid input or take-off. This would enable a preset rate of extraction to be maintained in a system.

The device gave satisfactory performance in laboratroy experiments. It has also been included in a liquid-liquid extraction semi-pilot plant for the extraction of tar acids at the Central Fuel Research Institute where its performance has been found to be very satisfactory. [Based on a paper by B. P. Sinha, C. S. B. Nair & A. N. Basu, published in *Research & Industry*, **16** (1971), 1, 35.]

Notes & News

Committee and Meeting

The Fourteenth Meeting of the Executive Council of the Central Fuel Research Institute was held under the Chairmanship of Sir J. J. Ghandy, Director, The Tata Sons Private Ltd, on Tuesday, 13 April 1971, at the CFRI, Jealgora.

In response to a request by Chairman, Dr Lahiri gave a broad outline of the achievements of the Institute during 1970-71. Speaking of formed coke process, he said that NCDC had taken a keen interest in the process and appointed consulting engineers to study the feasibility of its commercial exploitation. However, the NCDC now wanted substantial amount of formed coke for market trials which could not be supplied as the pilot plant project had not been sanctioned and established.

With regard to oil and chemicals from coal, Dr Lahiri said, further feasibility studies with greater emphasis on chemicals were conducted at the request of the Planning Commission and the Ministry of Petroleum & Chemicals. For development of a hydrocracking process including catalyst for treatment of heavy residues from Middle East crude for production of middle distillates, a project for collaboration with the Indian Oil Corporation was being drawn up. With regard to development of fluid bed combustion, several boiler manufacturing firms were approached.

In the chemical field, development contracts were signed with Chemical & Metallurgical Design Co. (P) Ltd for four processes, e.g. 3-cyanopyridine, 4-cyanopyridine, benzoic acid and benzaldehyde and for purification of anthracene. For production of anthraquinone, a consulting engineering firm in Bombay had been appointed and they were negotiating with Hindusthan Organic Chemicals for offering a turn-key plant.

For selective preparation, Tata-Robins-Fraser were approached; for the Oleoflotation Process, a development contract had been signed with McNally-Bird Engineering Co., who along with McNally-Pittsburgh of USA were developing the process; and for production of fly ash bricks negotiations were carried out with a subsidiary of M/s Andrew Yule & Co. Ltd.

Enumerating the important developments at the Institute during the year, Dr Lahiri referred to: (i) Development of a process of making pelletized domestic coke for the utilization of washery middlings; (ii) a technique of demineralization of coals and middlings resulting in a product with as low as 2-2·5 per cent ash for coal and less than 15 per cent ash (with 50-60 per cent yield) from middlings; (iii) a process for the production of maleic anhydride from benzene; (iv) trials on indigenous spathic iron ore located by CFRI for hydrogen production, which is wanted by a number of industrial units; (v) development of an efficient hydrocracking catalyst; (vi) conception of a novel sponge iron making process; (vii) method of making coke for the ferro-silicon manufacture; (viii) fluid bed combustion; (ix) state of iron in catalysts; (x) direct oxidation of coal to produce polynuclear chemicals; and (xi) nitro-humic acid incorporating micro-nutrients.

Dr Lahiri mentioned that the process of production of sponge iron conceived by the Institute might have major impact on the pre-reduction of pellets or sized iron ore.

In the field of coal gasification, the Director, Dr. Lahiri, stated that the Institute devoted already considerable efforts on development of conventional techniques of gasification of coal, at elevated pressure and at atmospheric pressure. All data on suitability of raw material, oxygen steam requirement, efficiency, etc., were available.

Referring to the progress report of 1970-71 of CFRI, the Chairman observed that the Institute had another successful year of research and development. He congratulated Dr Lahiri, the Director, for covering wide range of projects involving generation of power, operation of power stations, operating and setting up of beehive ovens, operation of byproduct coke ovens, byproduct recovery and processing systems, production of domestic fuels by various processes developed at the Institute, fuel efficiency problems, supply of coal and coke to steel plants, beneficiation of coals in commercial washeries and study of their operational efficiencies, utilization of lignite and so on. He was also pleased to note that the Institute was continuing to give aid to the various public sector projects for development of coal and other heavy industries. He felt that all these indicated the growing importance of the Institute in the context of industrial development of the country and was confident that with increasing tempo of the Fourth Plan and perspective planning for the Fifth Plan, the Institute would be called upon to shoulder additional responsibility.

Discussing the research programme for 1971-72, which was strongly endorsed by the Scientific Committee and especially the reorientation of the Fourth Plan programme, the Chairman expressed his hope that the Committee would agree with him that this was not only a balanced programme of research extending over a wide field, but also covered important areas of R & D. He also noted the increasing importance and orientation of research programme in the field of chemical technology including petroleum refining techniques. These projects might be considered as border line disciplines now, but with the setting up of the petro-chemical complexes in the eastern region for large-scale production of aromatic and tar chemicals from steel plants, such a change of emphasis on programme might be welcomed as long as the bread-and butter problems of fuel technology were not neglected.

He then referred to the growing collaboration of the CFRI with consulting engineering firms and commercial organizations. In this context, he was glad to note that the feasibility report prepared by Chemical & Metallurgical Design Co. (P) Ltd on production of formed coke from non-coking coals by the CFRI process had struck

an optimistic note and it was time that this pilot plant project on formed coke including fluid bed carbonization should receive the full support of CSIR without any further delay.

The Chairman also observed that the Institute had developed a satisfactory process for production of pelletized smokeless domestic fuel from washery middlings and rejects, whose off-take continued to be a major problem for coking coal washeries. The solution presented by the Institute's process has now assumed considerable significance.

Amongst other agenda, the Council approved the various sponsored projects undertaken by the Institute and endorsed the taking up of new sponsored projects, e.g. (1) Hydrocracking of Vacuum Distillates from Middle East Crude Oils to be sponsored by M/s Indian Oil Corporation; and (2) Selection of a Suitable Coal Blend for BSL sponsored by M/s Bokaro Steel Ltd.

Regarding release of patents and processes, the Council approved of the constitution of a Standing Committee. The Council suggested the inclusion of Mr S. B. Sarkar, Chief Combustion Engineer of the Coal Board, as an additional member and Dr N. G. Basak, Deputy Director, CFRI, as Secretary to the proposed committee in which the Director, CFRI, would be a member. Other members of the committee nominated were from various industries and educational institutes.

The Council noted the need for the catalyst sintering furnace in connection with the sanctioned project on catalyst preparation and sanctioned Rs. 52,000 for the purchase of the furnace from M/s Ceico Private Ltd.

The Council concluded the meeting after discussing other points related to the smooth functioning of the Institute.

■ The Eighth Meeting of the Advisory Committee for the Coal Survey Laboratory, Jammu, was held in the conference room of the J & K Industries Ltd, Srinagar, on Saturday, 1 May 1971 at 3 p.m.

The Committee was informed of the exploration work taken up by the Directorate of Geology & Mining, J & K State, in Chakkar coalfield in order to demarcate areas of desired ash percentage. In this connection trench samples from Upper and Lower seams in Khori block have been analysed by the Coal Survey Laboratory. The samples supplied by the Directorate were found to be weathered. This suggested the need for close contact between the Directorate and the Survey Laboratory at the time of site selection.

The Committee was intimated of the occurrence of medium quality coal in Tirath Area of Chakkar coalfield. The prospecting of the area was suggested on a priority basis as the coals would constitute the feed to the Kalakot Thermal Power Station.

To meet the requirements of low volatile, medium ash (22-25 per cent) coals of Kalakot Thermal Power Station, CFRI suggested that detailed washability tests on the coals of Bergoa, Chakkar and Jangalgali coalfields should be undertaken. Middlings with about 35 per cent ash may be used for domestic coke making and rejects containing more than 40 per cent ash for brick burning after mixing with fines to reduce ash content.

The Committee was apprised of the successful briquette-making operation of the Survey Laboratory from Bergoa and Jangalgali coals. It was considered necessary to undertake combustibility tests on the briquettes at CFRI HQ. Studies on briquette making using slack coal, lignite and pine sawdust in suitable proportion were suggested.

Encouraging results were reported to the Committee on the quality of two samples of coal from Himachal Pradesh. It was reported that prospecting of the area was being taken up shortly.

■ The first meeting of the Standing Working Committee for Petroleum, Coal and their Derived Products (SWCPC), was held at New Delhi on 30 April 1971 with Dr J. S. Badami, Managing Director and Chairman of Swastic Oil Mills, in the Chair. Dr A. Lahiri, Director, CFRI, was the Vice-Chairman of the Committee.

Dr Badami, explaining the need for setting up of new standing working committee stated that there was steady increase in demand for coal, coke, petrochemical products, etc. Simultaneously, the refining capacity and demands for variety of petroleum products like naphtha, motor gasoline, kerosene, diesel fuel, fuel oil, etc., were also growing. It has also been noted that the organic chemical industry has been moving from its conventional raw materials like coal, alcohol, calcium carbide, etc., towards petro-chemical based materials. In this context, another matter of concern was the increase in the price of crude and the consequent need to save foreign exchange by substituting the petroleum products wherever possible by the use of electricity, coal, coke and like materials to meet the demand for energy. There was also scope for changing production pattern of the refineries with a view to getting more production to meet the requirements of our country. Therefore, in today's context, it is necessary and desirable to review the existing specifications and to intensify standardization activities in this field. With this larger perspective in view, it was felt necessary by the Chemical Division Council that the subject of petroleum, coal and their products be grouped together and placed under the supervision of a single and distinct Standing Working Committee so that the standardization activity in these fields could be better coordinated and intensified in the interest of the country. He also expressed that in the view of the growth rate and vast potential of petroleum, coal and their derived products in the country, it was likely that in the near future this Standing Committee would have to be raised to the level of Division Council.

Dr Lahiri welcoming the formation of this Standing Committee, referred to the fact that setting up such committee was mooted by the Solid Mineral Fuel Sectional Committee (CDC 40) and stated that it was necessary to have a careful look into the present practice of being guided largely by standards of overseas country in formulating Indian standards. Due to the incompatibility, compromises are agreed upon and these are not always satisfactory to manufacturers and consumers. He also stated that for products derived from petroleum and coal which have many end uses, there was need for developing suitable methodology to ensure the active association of all concerned in the framing up of specifications for such raw materials so that the standards produced were widely accepted and adopted without difficulty. For the purpose he recommended joint meetings of committees concerned.

Mr S. K. Sen, Director-General, ISI, further emphasizing this point stated that protection of the interest of the ultimate consumer, who in this case very often was the man in the street, would have to be ensured.

Dr Lahiri also spoke about the need to keep the environmental effects of industrial activity in mind while framing or reviewing the specifications. After further deliberations, the SWCPC agreed that the following would be its scope of work: (a) basic organic chemicals and intermediates derived from petroleum or natural gas, (b) acetylene, (c) fermentation products such as alcohol, and (d) coal and its products, coal mining, beneficiation practices; fuels and natural gases, petroleum products (including tar and bitumen), and lubricants including their test apparatus.

Fly Ash for Remote Filling of Mine Voids

US Bureau of Mines reports that fly ash may in future do a great deal to rectify some of the ill effects of early mining and may be able to assist in solving some of the mining problems of today. It is also stated that fly ash is being used or will be tested for the following: to control abandoned mine fires; to prevent abandoned mine subsidence; for remote sealing in active mines; to extinguish mine refuse dump fires; for backfilling in active mines to prevent methane drainage or to prevent surface subsidence; for remote filling of abandoned mine entries to prevent acid mine drainage; and for slurrying into abandoned mines for economical disposal.

There are two different types of mine voids which must be filled to cope with the problems of abandoned mine fires and subsidence. These are the open entry and the loose underground rubble. The way to extinguish an abandoned mine fire or to prevent surface subsidence is to develop an effective method of remotely filling underground mine voids. The eroding out and collapse of the support pillars that cause abandoned mine subsidence can be prevented by filling the open voids around the pillars to prevent their erosion and to stabilize the pillars in place. This can be done by the injection of dry fly ash through boreholes. The dry fly ash in place absorbs moisture, which is always present in an abandoned mine, and becomes firm. In addition, there is some evidence that this fly ash mass expands slightly as it takes moisture.

The prevention and extinguishment of abandoned mine fires can be accomplished by using two injection techniques because there are two types of voids involved. Dry fly ash injection is used to fill open voids to stop ventilation of the fire area and to create barriers around the fire. Fly ash-water slurry injection is used to penetrate into the caved, porous material. This penetration creates a solid mass through which air cannot filter, thus smothering the fire. The injected fly ash builds up from the floor of the cavity to the bottom of the borehole and is then forced outward along the roof of the cavity by the available injection pressure, which is generally about 20 psig. The finely divided state and the physical properties of the fly ash allow it to readily penetrate voids to form a stable, non-settling plug. Fly ash is particularly adapted to the sealing of large void spaces owing to its extremely low angle of repose, 8 deg, excellent roofing characteristics, low density, non-settling properties and tendency to become firm when exposed to moisture. [*Coal Age*, (May 1970), 86.]

Fluid Bed Reactor Defeats Naphtha Shortage

The demands for naphtha as the major source of olefines, as an octane number improver, and as a source of aromatics compels the search for an alternative feedstock for olefine manufacture. There is, therefore, considerable interest in any process which accepts a heavier oil or even crude oil as its feed. Ube Industries have developed such a process, its heart being a fluidized bed reactor of novel design. Among the salient features of this reactor are the following: an operating temperature of 830-880° C., achieved by a measure of partial combustion of the feedstock, residence time of 0·2-0·3 sec, a bed of ceramic oxides granules of high heat and abrasion resistance, and funnel-shaped gas distributors which produce forced circulation of the granules within the bed. The consequence of this latter feature is a capacity, an order of magnitude or more greater than that of conventional pyrolysis fluid bed reactors.

The process is remarkable in other respects. Examples are the procedure for preparing the bed granules for quenching the reaction products which rely upon fluid bed technology. The snags in using tubular equipment for quenching, particularly the fouling of the tube surfaces, justifies the use of liquid bed type quencher, in this example the cooling takes place through direct contact with a stream of water or light hydrocarbon. A regeneration combustion step cleans the particles which then return to the quencher. [*Brit. chem. Engng* (January 1971)].

Spherical Agglomerates Make Good Coke

Canadian industry is showing increasing interest in a process developed by the National Research Council (NRC) of Canada for turning low grade coal into coke for iron ore blast furnaces. The process, developed by NRC's Chemistry Division, provides a method, known as spherical agglomeration, which rapidly and efficiently separates solids from liquid suspensions.

Initial research showed that crystals of barium sulphate suspended in benzene formed spheres (agglomerated) when small quantities of water were added. Also, the crystals were coated with a layer of water which acted as a binding material to hold them together when they touched. Later work showed that recovery of valuable particles in slurries (suspensions of insoluble particles in a liquid) could be made easier if the particles were coated and agglomerated. Wetting agents, including oils, were discovered that allowed the successive agglomeration and selective recovery of several different particles in a slurry.

Spherical agglomeration facilitates separation of the carbonaceous elements from much of the sulphur, ash and water found in coal fines — coal crushed to a fine powder. The carbonaceous constituents of an aqueous pulp of coal are removed in the form of pellets from the suspension in which a variety of oils are used as the bonding agent. The pelletized coal product is suitable for coking.

It is estimated that agglomeration should become economically feasible if a large-scale operation can be evolved that would reduce ash and water content of coals to an acceptably low value. A semi-pilot scale plant capable of treating about 90 kg of coal slurry an hour is now operating in the Chemical Engineering Section of the Division of Chemistry. New Brunswick coal fines containing 20 per cent moisture, 20-33 per cent ash and 7 per cent sulphur have been upgraded to coal pellets containing less than 0·5 per cent moisture, 5 per cent ash and .2 per cent

sulphur. Low grade western Canadian coals have responded similarly.

The Federal Department of Energy, Mines & Resources has established a pilot plant in Ottawa to collaborate in the work and to assess the coking properties of the pelletized coal produced by the agglomeration process. The tests indicate that the quality of the coke produced from coal partly or entirely made up of agglomerates is equal or somewhat superior to that made from normal coal charges. [*Science Journal*, January 1970, 19.]

STAFF MATTER

Promotions

We congratulate the following on their promotion:

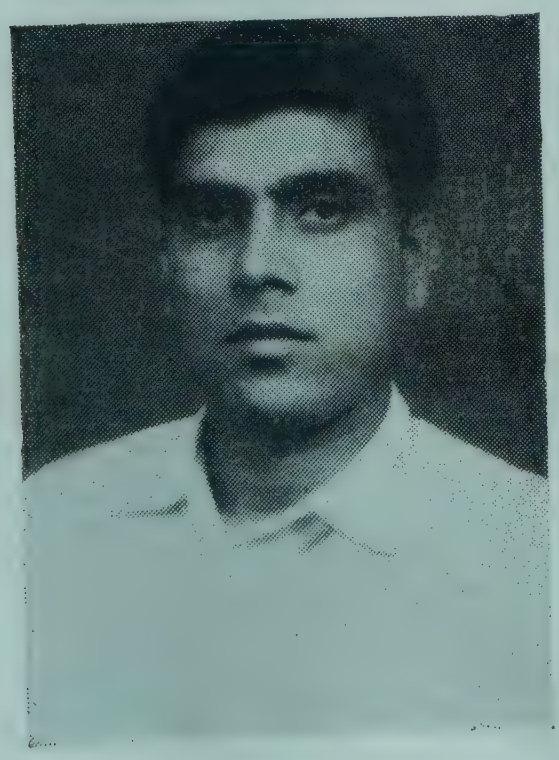
(i) Shri K. K. Roychowdhury — Promoted to Scientist 'C' (w.e.f. 5 March 1967) on the recommendation of the Assessment Committee, Shri Roychowdhury graduated in science with distinction in 1954 from Calcutta University and took M.Sc. degree (1st class) in geology from Jadavpur University in 1956. He is also an Associate of the Institute of Chemists (by examination).

Shri Roychowdhury joined CFRI in 1957 as senior scientific assistant and was later promoted to JSO (in 1958) and SSO II (in 1961).

Shri Roychowdhury started his career at CFRI in the Geology Division, and later joined the geology group of the Coal Survey Laboratories of Jharia, Bilaspur and Raniganj successively. At Raniganj, he worked for the Coal Assessment Committee of Coal Council of India. Shri Roychowdhury was later in-charge of Bisrampur substation of the Bilaspur Coal Survey Laboratory.

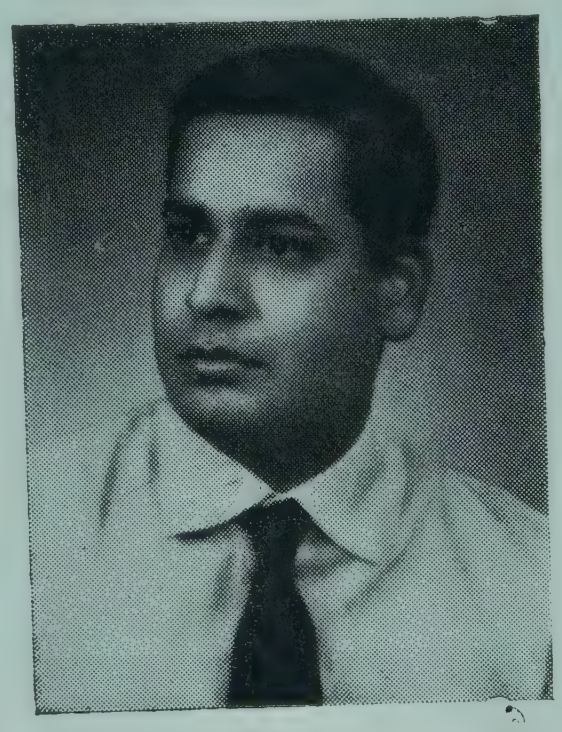
Sampling of coal for central washeries and assessment of borehole cores from virgin coal-bearing areas have been the important assignments of Shri Roychowdhury. His other important work comprises drawing of seam folio maps with particular reference to thickness, quality, overburden ratios, etc., and iso-ash, iso-vol maps of different coalfields.

An author of seven research papers and a report on Chirimiri Coals, Shri Roychowdhury is also responsible for drafting a number of coal survey technical reports.



K. K. Roychowdhury

(ii) D. Bagchi — Shri Debtosh Bagchi (b. 1 January 1934) was promoted to Scientist 'C' (w.e.f. 6 September 1969) on the recommendation of Assessment cum Selection Committee. He obtained his B.Sc. (distinction) from the Calcutta University in 1954 and M.Sc. in geology (1st class, 3rd) in 1956 from the Jadavpur University. He joined the CFRI as JSA in 1957 and was successively promotted to SSA (1958), JSO (1959) and SSO (1962). He took up research on coal petrology which formed the subject of his thesis during his postgraduate studies. Coal metamorphism was traced by him through systematic determination of reflectance of vitrain from lignobituminous coals to South Wales anthracite. Shri Bagchi was transferred to the Coal Survey Laboratory at Raniganj in 1967. For 3 years (1962-65) he was associated with the Coal Assessment Committee, during which time he was actively engaged on the work of quality survey of West Bokaro and Ramgarh coalfields. He has to his credit many research and review papers, including one on 'Petrographic Nature of Lithotypes' presented to the International Geological Congress held in Paragues, Czechoslovakia, in 1967. He has also contributed to the compilation of many reports from the CSL, Raniganj.



D. Bagchi

(iii) Shri D. K. Bhattacharjee to Scientist 'C' w. e.f. 6-9-1969 [Biography of Shri Bhattacharjee will be published in a later issue of the News.] — *Ed.*

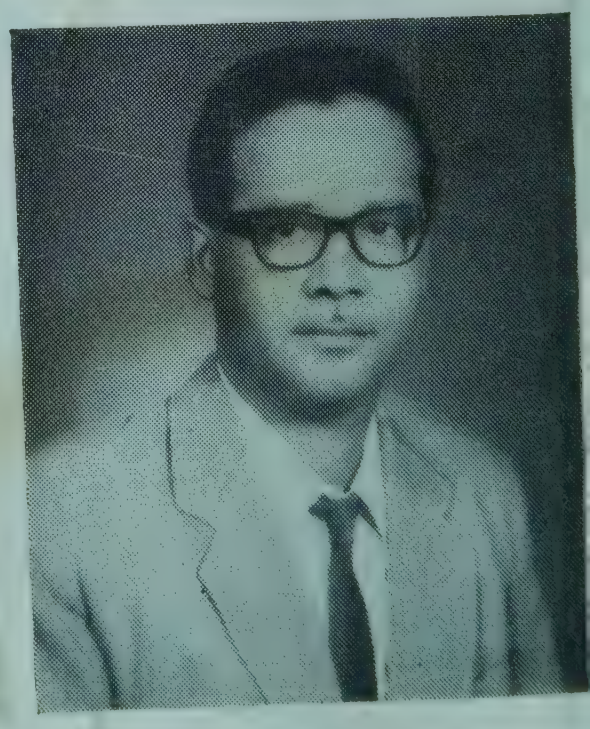
(iv) Sarvasree B. Nandi and D. K. Roy to Junior Technical Assistant.

Deputation

(i) Dr A. Lahiri, Director, visited USA from 30 June 1971 for a period of two weeks to attend the Gordon Research Conference on Coal Science (1971) at New Hampton, New Hampshire (on invitation), Bruceton and Chicago for appraising himself of trends in recent research and pilot plant developments on fuels and allied materials and Pittsburgh (Kansas), for consultation with M/s McNally Pittsburgh in connection with the commercialization of the CFRI process on Oleoflotation.

Dr N. G. Basak, Deputy Director, discharged the functions of the Director during Dr Lahiri's absence.

(ii) Shri R. N. Bose, Scientist, left CFRI on 25 August 1971 for Poland for a six-month training in coal preparation technology under the exchange of scientists programme between CSIR and the Polish Academy of Sciences.



Mr R. N. Bose

(iii) Shri P. K. Basak, SSA, was deputed to the Indian Institute of Mass Communication for training for a period of 3 months with effect from 3 August 1971.

Honours/Awards

(i) Dr A. Lahiri, Director, has been nominated to represent CSIR in the Indian National Committee, World Energy Conference.

(ii) Shri A. K. Palit, Stores and Purchase Officer, has been elected member of the National Association of Materials Management, Bombay, and the Purchasing Officers' Association of India, Calcutta.

(iii) Shri K. K. Tiwari, SSA, was awarded the degree of Master of Science by the Patna University and was placed in 1st class.

(iv) The following successfully completed the examination for the Associateship of the Institution of Chemists (India): Sarvasree Amiya Kr. Chatterjee, P. K. Mitra, Md. Bashiruddin, Bhaskar Nandi, Nikhil Ch. Basak, Satya Kinkar Mitra, Prodyot Kr. Sarkar, and Rajiv Ranjan Prasad Roy.

Transfer

We express our best wishes to Shri R. P. Raut, Section Officer, who has been transferred to Central Glass & Ceramics Research Institute, Calcutta, w.e.f. 16 August 1971 (AN).

Resignation

We wish all success to the following of our colleagues who have left CFRI for employment elsewhere: Shri Ranjan Chatterjee, JRF, and Dr D. P. Bhattacharjee, Scientist 'B'.

OBITUARY

Shri K. P. Banerjee

The following resolution was moved in a largely attended condolence meeting of the CFRI scientists and staff with Mr S. K. Das Gupta, Deputy Director, in the Chair. Shri B. C. Dey, Assistant, Bill Section, read out a piece eulogising the qualities of Shri Banerjee.

Condolence Resolution

We, the members of staff of CFRI, deeply condole the sad and untimely demise (13 July 1971) of Shri K. P. Banerjee, SO (Officiating), CFRI, and pray for the eternal peace of the departed soul. To the bereaved family we express our heartfelt sympathies.

Shri Banerjee joined the Institute as early as in January 1948 when the present laboratory was a mere hutment and was housed in a large shed in the campus of Indian School of Mines, Dhanbad. Along with the shifting of the Laboratory in 1949 to its present location, Shri Banerjee came over as the Clerk-in-Charge of Jharia Coal Survey Laboratory. Shri Banerjee was promoted to UDC in the year 1950 and was assigned to the General Office. In view of his hard, sincere and diligent work, Shri Banerjee was promoted to the rank of an Assistant in 1958. He took over charge as officiating Section Officer, Coal Survey HQ in November 1970.

Besides being sincere and very devoted to his duties, Shri Banerjee was all smiles and of amiable nature. This won him the admiration of all. His beaming face will ever remain in our memory.

CFRI ABSTRACTS

A Programme of Integrated Development of Fossil Fuel Resources in Assam (India), by A. Lahiri & D. K. Mukherjee [Presented to the World Energy Conference, Bucharest, 27 June to 2 July 1971].

The paper presents a proposal for location of a commercial plant for conversion of coal to oil and chemicals in Upper Assam, India. The properties of the coal, unlike those of the penninsular India, are unique. These high sulphur tertiary coals are perhaps the most 'hydrogenable' coals in the world. The coals also occur in the vicinity of petroleum and gas reserves and in th same geological horizon. The mixed base natural crude of Assam is also best treated by hydrorefining and, therefore, can be treated in a common refinery where the facilities for treatment of the natural and synthetic crudes could be combined, e.g. for hydrogen production, distillation, hydrorefining, aromatic extraction, heating, steam, gas supplies, etc.

Techno-economic feasibility of production of oil and chemicals from these coals alone, with or without the use of natural gas as feed stock for hydrogen, is examined. The study also covers an integrated coal-oil refinery working up both synthetic and natural crudes.

An economic unit for coal-to-oil programme will be at least 60,000 bpd. A project of this magnitude cannot at present be justified in India. The case for a smaller plant, 30,000 bpd was, therefore, studied by carying product patterns for improving its economics. The calculations indicate that by incorporating production of chemicals, several alternatives can yield satisfactory ROI. The ROI is maximum when two-third of the products are chemicals.

Substitution of natural gas for heating by producer gas from coal lowers the return by about 2 per cent still offering an acceptable ROI. The integrated refinery, where the chemicals to fuels ratio is approximately 2:3, has the lowest ROI (12·7 per cent) before tax integration, and yields a product pattern flexibility for other downstream projects which can be of economic significance.

The project has an important bearing on national economy in so far as it will usher in a new technology, while meeting economically, the demands of various chemical feed stocks, fertilizer, sulphur and liquid fuels, especially the middle distillates.

A Coal-based Resource Development Plan for the Upper Gangetic Valley, by A Lahiri, N. C. Sinha, S. K. Sen & K. C. Lahiri [ibid].

A coal based resource development plan for the Upper Gangetic valley is described. It envisages production of about 22 m.t/y of sub-bituminous coal of Singrauli coalfield. The project, based on the concept of minimum transport of coal, raw materials or power, is divided into three major groups.

Energy products — Include production of: (a) electricity from raw inferior grade coal and middlings (@ 7 mt/y), totalling about 2000 MW; (b) high Btu piped gas (33×10^{12} Btu/y); (c) piped washed coal to consumer based power stations (@ 4 mt/y); and (d) industrial and domestic fuels, devolatilized char (0·93 mt/y), partly converted to formed coke (0·81 mt/y); and (e) a small quantity of coal for rail transport.

Metals — Only production of metals by electro-metallurgy is planned: (a) aluminium (82,000 t/y); (b) special steels and alloys (0·5 mt/y).

Chemicals —(a) Fertilizers (0·7 mt/y NH_3, 1·16 mt/y urea); (b) carbochemicals for Fischer-Tropsch products; and (c) tar chemicals and carbon products.

Availability of resources, market and basic economics are discussed. The project is considered as an economic development plan which will support agricultural and industrial development of the densely populated valley and provide gainful employment.

Mode of Occurrence and Properties of Coal Seams in and Around Madhukunda-Poradiha Area, Raniganj Coalfield, by Anoop K. Mukherjee, D. Bagchi & Anil K. Mukherjee [*J. Min. Met. F.* XIX (1971), 4, 99].

A quality survey in relation to the structural peculiarity of the potential seams of the Raniganj Measure in the south-western part (Madhukunda-Poradiha area) of the Raniganj coalfield is presented. The study reveals that there is a significant deterioration of quality as well as maturity of the coal seams from west to east. The borehole data reveal that the Dishergarh seam (R-IV) is found to occur at a very shallow depth around borehole No. RN-14, thereby indicating a probable outcrop of ironstone shales (Barren Measures) adjacent to this borehole, and the Barakar Measure rocks are also expected within approachable depth around the borehole in the area. Central sector of the area appears to be most promising with potential reserves of caking/blendable type of coal.

A Résumé of Research on Assam Coals, by A. Lahiri & S. Ranga Raja Rao [*J. Instn Engrs India*, **50** (July 1970), 166].

Assam has a sizeable reserve of about 4000 million tons of coal, besides petroleum and natural gas. The coal is of tertiary origin with characteristics midway between coal and petroleum. It has high organic sulphur, low phosphorus, low ash and high caking properties. These properties have evoked considerable interest in their industrial potentiality. The extensive studies carried out by the CFRI suggest that these coals are suitable for (a) blending for metallurgical coke manufacture, (b) cement manufacture, (c) power generation, (d) gasification for production of fertilizer, and (e) conversion to oil and chemicals. From a long-term point of view, the large reserves of upper Assam coals provide a great potential for supplementing the petroleum reserves of the country by converting them into synthetic oil through the direct hydrogenation technique. The process is especially attractive as valuable byproducts like sulphur, tar acids, petroleum coke are also obtained

Size Reduction, by B. Acherjee [*J. Instn Engrs India*,

51, 10, Pt. CH3 (June 1971), 53].

This paper discusses the mechanism of breakage in mills and the factors influencing the selection and operation of mills The discussion is confined to the conventional type of mills.

NEW WASHABILITY DIAGRAM PRESENTING THE PETROLOGICAL CONSTITUENTS OF COAL, by G. G. Sarkar, H. P. Das & K. C. Lahiri [*Canadian Institute of Mining Bulletin*, (January 1971), 57].

The petrographic components of any particular rank of coal often show some distinct physical and chemical characteristics. Therefore, their proportionate distribution in a coal greatly influences the technological behaviour of the coal.

In any size of gravity separation of a coal, the petrographic constituents become segragated to different degrees in some preferred size of specific gravity range. Therefore, a knowledge of the petrographic nature of the washed and/or screened fractions is often considered essential in selecting the most efficient method for coal preparation and in exploring the proper avenues for its utilization.

A graphical method is described in this paper to indicate the mineral-matter content and the petrographic components of the washed fractions of a coal at different ash levels of separation in the form of a new washability diagram. This diagram can be conveniently used to assess or predict the petrographic composition of clean coal or sinks corresponding to any desired ash level in the cleans. With the help of this diagram, it is also possible to locate the yield level of cleans at which maximum enrichment of vitrinites and exinites occurs with the least amount of mineral-matter content.

MODERN TRENDS IN IRON & STEEL INDUSTRY, by P. C. Ghosh & A. Lahiri [*J. Min. Met. F.*, XVIII (1970), 11, 12].

Basic concepts and scope of pre-reduction, direct reduction of iron ore and its agglomerates, and rationale of an alternative steel route based on reduced stock have been discussed in the first part. In the second part have been depicted rising world steel capacity and output, rising international steel trade, also the state of the industry in India and abroad. Trends in enlarging both company size and unit size, profitability on investment in steel, productivity, capital size, use of computer, importance of transport have been elucidated in the third part. Scope of research and development, investment, investment on return from research, important innovations have been discussed in the concluding portion.

STUDIES IN THE SYNTHESIS OF 2: 4-DICHLOROPHENOXYACETIC ACID, by M. S. Anand & C. S. B. Nair [*Indian J. Chem.*, V (1971), 9, 19].

The methods available for the preparation of phenoxyacetic acid from phenol and chloroacetic acid and for the production of the 2: 4-dichlorophenoxyacetic acid have been compared and conditions established for obtaining consistently good yields. The yield of phenoxyacetic acid obtained was 82·28 per cent on theoretical and by chlorinating this, the 2: 4-dichloroderivative was obtained in 81·4 per cent yield on theoretical. The conditions for the chlorination of acetic acid to the monochloroderivative with a yield of 74·7 per cent on theoretical has also been worked out.

SOME TYPICAL INDUSTRIAL FUEL EFFICIENCY TESTS CONDUCTED BY CFRI, by D. K. Biswas, R. R. Biswas, M. N. Juneja, D. K. Mukherjee, G. Pal, M. Sen & S. K. Dasgupta [Presented to the National Seminar on Fuel Efficiency, N.P.C., New Delhi, 15-17 Oct. 1970].

The salient features of some important fuel efficiency tests conducted by the Institute in power plant boilers and process industries are discussed with a view to focusing the varied nature of problems involved and efforts made to solve some of them. The need for a concerted effort by all concerned towards achieving maximum fuel efficiency has been stressed.

PRESSURE GASIFICATION OF SOME NON-COKING COALS, by D. K. Biswas, R. R. Biswas, J. R. Mitra, S. K. Mitra, R. N. Bhattacharjee, M. N. Juneja, A Mazumdar & M. M. Sen [*Indian J. Technol.*, **9** (1971), 63-69].

The fixed bed pressure gasification pilot plant installed and commissioned for experimenting with Indian coals is described. The results of gasification trials performed with typical non-coking coals of Talcher field (Orissa), Raniganj field (West Bengal), Singareni field (AP) and Sohagpur field (MP) are presented and discussed. The performance of the gasifier, judged from the value of gas yield and quality, percentage carbon gasified and cold gas efficiency, has been examined in relation to the plant pressure employed. Well-defined relationships have been found to hold good in most of the cases examined. The requirements of the principal raw materials, namely coal, steam and oxygen for producing 1000 Nm^3 of raw and CO_2 scrubbed gas have been worked out. Data concerning the yield of byproduct tar for the coals tested are given and detailed analysis of a tar sample is presented to illustrate the quality of byproduct tar obtainable. The tests conducted bear a special significance in the context of the country's expanding demand for synthetic fertilizers and chemicals, and oils and the need for developing the town gas industry.

coal in the pulverized form. The maintenance cost due to wear of the mill alone is often more than the cost of power required for grinding, but bad grinding can have serious consequences on the plant availability.

Though external erosion and corrosion are functions of mineral matter composition, coal preparation, combustion control and equipment specifications, internal erosion of boiler tubes is very much dependent on water treatment. There are no 'water consultants' of the standard and competence available abroad and many power stations rely on foreign firms or merely on supplies of water treatment chemicals or processes. Specialized training in this field and setting up of competent consultants could be of great benefit. The CFRI could help in setting up of such an organization, if it had the blessings of the Central Water & Power Commission and the Planning Commission as it can only be done on 'retained' consultation basis from the thermal power plants.

In the context of the development of power generation capacity and the complexities of power station operation, maintenance and management, a matter that requires urgent attention is the need for organizing training and refresher courses for the various categories of power station personnel — operators, engineers and managers. In earlier years, much of the training for the personnel was 'on-the-job'. Such a course is hardly possible in the present situation. Not only the rate of growth of generation capacity is exponential which requires quick availability of large number of trained personnel but also modern large capacity, high pressure and temperature units require special skills in regard to operation, maintenance and management. The large modern generating units, each rated at 100 MW and above with pulverized fuel fired reheat cycles are much different from the old stoker grate fired units of capacities in the range of up to 30 MW each. With these larger and highly complex units, the output per unit is also very high so that the cost of an hour's outage, in terms of money, is also very large. These facts make it risky and inadvisable to entrust the operation and maintenance of these plants to staff not specially trained for the purpose. Prevention of obsolescence at the management level is also highly important. These requirements can only be met by instituting special courses for combustion engineers and adequate refresher courses for the various levels of staff. In this endeavour, CWPC, State Electricity Boards and Research Institutions have a cooperative role to play. CFRI in its part will be glad to organize courses in fuel and heat utilization for the different categories of industrial personnel.

Surveying the field, one feels that perhaps a 'Boiler Availability Commission' set up by the Government should look into each of these problems mentioned and institute necessary measures for organizing remedies, R & D, consultancy services and training. The magnitude of the problem and the effect of lack of availability can have serious consequences on the economy of the country as a whole and justifies setting-up of a Commission to probe into the problem.

— A.L.

Chief Editor: S. RANGA RAJA RAO

Editor: SAMIR SEN *Assistant Editor*: R. S. SAHA

Yearly Subscription: Rs. 4 This Copy Re. 1

Available from

CENTRAL FUEL RESEARCH INSTITUTE, P.O. F.R.I., DT. DHANBAD, BIHAR, INDIA

PHONE: JHARIA 6205. GRAMS: RESEARCH, JEALGORA

PRINTED AT THE CATHOLIC PRESS, RANCHI

Registered with the Registrar of Newspapers for India Under No.

R.N. 3872/57

INDEX TO F.R.I. NEWS

Vol. 21 (1971)

GENERAL INDEX

EDITORIALS PAGE

Energy Resources Development in ECAFE Countries 1
Hard Coke Industry in India ... 37
Coal-based Power Stations 73

LEADING ARTICLES

Fuel and Energy Resources Development in ECAFE Countries 2
Utilization of Weakly to Semi-caking Coals of Madhya Pradesh 9
Natural Coke (Jhama): Its Properties and Potentialities 17
Hard Coke Manufacture in India ... 38
Coals of Pathakhera Area, Pench-Kanhan Tawa Valley Coalfield — An Appraisal 46
Trends in the Development of Lubricating Oils 52
Coal-based Thermal Power Stations — A Survey and Preliminary Studies on Their Problems in India 74
Abrasiveness of Coal and Associated Minerals in Relation to Pulverizer Wear 85
An Appraisal on the Quality of Coals of Kanhan Valley Coalfield 96

SPOTLIGHT ON SCIENTIFIC ACTIVITIES

Smokeless Fuel by Spherical Agglomeration 23
Silica Incorporated Briquettes as Improved Charge for Ferro-silicon Manufacture 24
CFRI Suggests Measures for Improved Operation of Beehive Ovens ... 25
Potentialities of VIII Seam of Jharia Coalfield as Coking Coal 26
Correction for Adsorbed Acid in the Carboxyl Group Estimation of Coal ... 26
Ortho-phthalonitrile from Ortho-xylene ... 58
Pine Oil as a Frother for Coal Flotation 59
Mechanism of Coal Pyrolysis and Industrial Practise 59
A Conceptual Structure for Assam Coal 60
Feasibility Study on the Utilization of Kutkona Coals of M.P. 104
Production of Anthraquinone from Anthracene 105
Rapid NMR Method of Estimation of Water 105
Phase Boundary Determination ... 106

NOTES & NEWS

Committee and Meeting

Expert Committee Meeting for the Examination of Dr E. E. Donath's Report on Hydrogenation of Assam Coal to Oil 27
Advisory Committee Meeting of RCSL ... 27
Conference on Research and Development in Industry 28
Research and Development Committee of CAC 29
UNESCO Seminar on Problems of Transition from Laboratory Research to Industrial Application 31
CFRI Scientific Committee Meeting ... 62
Annual Meeting of Indian Institute of Mineral Engineers 62
Coal Advisory Council Meeting ... 63
Annual General Meeting of the Indian Mining Association 64
Annual General Meeting of the Indian Colliery Owner's Association ... 64
Executive Council Meeting of CFRI ... 107
Advisory Committee Meeting of Jammu CSL 108
Standing Working Committee Meeting for Coal Petroleum and Their Derived Products 108

Notes

Coal Supplies to Vizag and Hospet ... 30
Trends in Fuel Research 32
Dr A. N. Ghosh, DG, ISI, Retires and Shri S. K. Sen succeeds 33
Coal Research Programme of the U.S. Bureau of Mines 64

Recent Advances in Research

High Grade Steels made more Cheaply ... 33
Hydrodesulphurization (HDS) Process ... 34
A New Cryogenic Hydrocarbon Extraction Plan 34
Polluted Water Treatment with Fly Ash 66
Lead-free Petroleum Fuel for Automobiles 66
Fly Ash for Remote Filing of Mine Voids 109
Fluid-bed Reactor Defeats Naphtha Shortage 109
Spherical Agglomerates Make Good Coke 109

Symposia/Seminar

Seminar on Fuel Efficiency 27
Role of Pone Resin in the Economic and Industrial Development of India ... 64

STAFF MATTER

Honours and Awards

Shri G. G. Sarkar Awarded National Minerals Award 34

PAGE

Sarvasree B. K. Mazumdar and N. N. Chatterjee's Article "Mechanism of Coal Pyrolysis in Relation to Industrial Practice" Fetched Silver Medal of COMA, 1970 35
Dr A. Lahiri, Nominated to Represent CSIR in the Indian National Committee, World Energy Conference ... 111
Shri A. K. Palit Elected a Member of Each of the National Association of Materials Management and Purchasing Officers' Association of India ... 111
Shri K. K. Tiwari Awarded M.Sc. Degree by the Patna University 111
Sarvasree A. K. Chatterjee, P. K. Mitra, Md. Basiruddin, B. Nandi, N. C. Basak, S. K. Mitra, P. K. Sarkar and R. P. Roy passed AIC 111

Deputation

Shri T. P. Ganguli to CEERI ... 35
Sarvasree G. S. Murthy, S. K. Chatterjee & Subodh K. Ray to Australia ... 111
Dr A. Lahiri to USA 110
Shri R. N. Bose to Poland 110
Shri P. K. Basak to Delhi 67

Resignation

Shri A. C. Bhattacharya 35
Dr A. K. Chowdhury 68
Shri Sibapada Ghosh 68
Shri R. Chatterjee 111
Dr D. P. Bhattacharya 111

Transfer

Shri R. P. Rout 67

Promotion

Shri V. A. Krishnamurthy to Scientist E 67
Dr M. Chakraborty to Scientist E ... 67
Shri K. K. Roy Chowdhury to Scientist C 110
Shri D. Bagchi to Scientist C ... 110
Shri D. K. Bhattacharjee to Scientist C 110
Sarvasree B. Nandi & D. K. Roy to JTA 110

Appointment

Dr S. C. Chakravorty as Scientist C ... 68
Dr D. G. Takte to Scientist C ... 68

Visitors

Shri D. K. Barooah 34
Prof. Andre Vamos 69

Obituary

Shri K. P. Banerjee 111

CFRI Abstracts

Regional Classification of Jharia Coals Based on Their Washability Characteristics 36
Crop Response with Humic Acids from Coal 36

PAGE

Formation of HCN by the Pyrolysis of Nitrogen-enriched Coal 36
Pore Structure of Low Temperature Chars 36
The Problems of Supply of Quality Coke for Industries 70
Beneficiation of Coking Coals in India ... 70
Groupwise Classification of the Barakar Measure Seams of the Jharia Coalfield 70
Blending and Stocking of Coals ... 70
Central Blending System 71
Coal Preparation and Handling Practice for Modern Thermal Power Stations ... 71
Pressure Gasification of Some Non-coking Coals 71
A Programme of Integrated Development of Fossil Fuel Resources in Assam (India) 112
A Coal-based Resource Development Plan for the Upper Gangetic Valley ... 112
Mode of Occurrence and Properties of Coal Seams in and around Madhukunda-Poradiha Area, Raniganj Coalfield ... 112
A Résumé of Research on Assam Coals 112
Size Reduction 112
New Washability Diagram Presenting the Petrological Constituents of Coal ... 113
Modern Trends in Iron & Steel Industry 113
Studies in the Synthesis of 2:4-Dichlorophenoxy Acetic Acid 113
Some Typical Industrial Fuel Efficiency Tests Conducted by CFRI ... 113

Maps, Plates, Flowsheets, Graphs, etc.

Sketch Map of Sonhat-Jhilmili Area ... 10
Sectional Make-up of Seams at Churcha-Kutkona Area 11
Flowsheet for an Integrated Project Based on Churcha-Kutkona Area ... 14
Production of Beehive Coke in India and USA 39
Production of Coke (Other than Beehive) in India 41
Iso-ash Map of Lower Workable Seam, Pathakhera Area 47
Iso-calorific Value Map of Lower Workable Seam, Pathakhera Area 48
Flow Diagram of Ortho-phthalonitrile Production from Ortho-xylene ... 58
Consumption of Coal for Power Generation 74
Map showing Thermal Power Stations, Washeries and Coalfields of India ... 77
Installed Energy Generation Capacity and Actual Output of Thermal Based Electric Power 78
Design of a Modified Abrasion Test Machine 86
Diagram of Roll Crusher Apparatus ... 86
Cross-section of Roll Showing Irradiated Insert 87
Relation between Mineral Hardness and Wear Rate of a Hardgrove Machine ... 89
Relation between Wear Rate and Abrasion Index 90
Relation between Wear Potential and Abrasion Index 90
Relation between Wear Rate and Shale Content 91

PAGE

Dependence of Wear on Grain Size of Quartz Addition to Feed 91
Effect of Quartz and Pyrite on Abrasion Index 92
Assessment of Wear in Coal Pulverizer ... 95
Sketch Map of Kanhan Valley Coalfield 97

Tables

Properties of Churcha-Kutkona Coals ... 12
Comparative Properties of Semi-coke and Formed Coke from Churcha-Kutkona Coals 15
Properties of Jhama from Different Coal-Fields 18
Chemical Composition of Dyke and Ash from Jhama and Coal 19
Size Degradation of Jhama on Storage... 20
Properties of Jhama and Foundry Coke 20
Physical Properties of Jhama and Hard Coke 21
Analysis of Pig Iron using 100 per cent Jhama and 100 per cent Hard Coke as Split Charge 21
Chemical Analysis of Slag and Metal from Cupola Tests with Jhama 21
Analysis of Pig Iron, Slag and Top Gas using 100 per cent Jhama ... 22
Low Shaft Pilot Plant Trial for Pig Iron Production using Jhama 22
Byproduct Coke Production in various Countries 42
List of Beehive Ovens 43
List of Byproduct Coking Plants ... 43
Indian Standard Specification for Hard Coke 43
Indian Standard Specification for Blast Furnace Coke 44
Indian Standard Specification for Gas Coke 44

PAGE

Indian Standard Specification for Foundry Coke 44
Indian Standard Specification for Coke for Ferro-alloy Industries 45
Disposition of Coal Seams in Pathakhera Area 46
Properties of Coals of Pathakhera Area 49
Washability Characteristics of R.O.M. Coals from Pathakhera Area ... 50
Properties of Pathakhera Cleans and Sinks 50
Production of Different Petroleum Products in the German Federal Republic 32
Viscosity Distribution of Motor Oils for Internal Combustion Engines in Hungary 53
Types of Lubricating Oil Additive Used in Hungary 56
Important Operational Features of Large PF Fired Thermal Power Stations ... 75
Effect of Steam Pressure and Temperature and of Reheating on Heat Consumption per kWh 84
Factorial Experiment with Newdigate Coal in Abrasion Apparatus 92
Factorial Experiment with New Sheldon Low Main Coal in Abrasion Apparatus 93
Factorial Experiment with Burdon Mill Coal in Abrasion Apparatus ... 93
Geological Features of Seams of Kanhan Valley Coalfield 98
Chemical Analyses of the Coals of Kanhan Valley Coalfield 99
G.K. Assay Results of Working Sections of Kanhan Valley Coalfield ... 102
Physical and Chemical Properties of Coals of III Seam, Top Section, Kanhan Valley Coalfield 102